ELECTRIC SYSTEMS CONSULTING

DAKOTAS WIND TRANSMISSION STUDY

TASK 1
Non-Firm Transmission Potential to Deliver Wind Generation

TASK 1 FINAL REPORT

REPORT NO. 2005-10977-1 R5
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Technical Report

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Summary

This report documents the status of results for Task 1 of the Dakotas Wind Transmission Study. The results and major conclusions from this study are:

1. The wind generation at each of the seven sites was predicted for the year 2003. The generation at each site varies from minimum to maximum throughout the year and indicates an average annual capacity factor at each site around 40%.
2. Benchmark cases for each interface were simulated with GridView and compared to the metered data for 2003. The NDEX and Ft. Thompson interface flows closely correlate between GridView and the measured values with the Watertown interface not as closely correlated due to its interdependency on Big Stone generation levels.
3. GridView simulations were completed for the historical year of 2003 and for a high hydro year for the wind generation at each site. A description of GridView is included in Appendix D. These simulations show:
   - For the 2003 year, NDEX transfers were above the NDEX limit for the three North Dakota sites for only a few hours each year. The results are similar for the high hydro year.
   - NDEX was exceeded most with wind at the Garrison site. For 2003 simulations the NDEX limit was exceeded for 14 hours with 849 MWh undelivered during the year and for the high hydro simulations NDEX was exceeded for 32 hours with 2256 MWh undelivered during the year. For either case this is less than 0.1% of the energy generated at the Garrison site.
   - No overloads were seen on the other interfaces with the wind generation.

The main conclusion from this study is that under normal system intact conditions, non-firm transmission is available most of the time across the three monitored interfaces for up to 500 MW at any one of the seven wind sites studied.

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Rev. 4	**Revision** Revised with Comments	**Date** 8-10-05	**Author** DM	**Reviewed** RV	**Approved** WW
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Table of Contents

1. INTRODUCTION

2. DEVELOP HOURLY WIND GENERATION

2.1 Description of Method for Developing Hourly Wind Generation
2.2 Calculated Hourly Wind Generation

3. DEVELOP GRIDVIEW DATABASE FOR HISTORICAL 2003 YEAR

4. INTERFACE POWERFLOW RESULTS WITH WIND GENERATION

4.1 2003 Low Hydro GridView Results
4.2 High Hydro GridView Results
4.3 Summary of Results

APPENDIX A – PLOTS OF LOW HYDRO CASE INTERFACE FLOWS WITH WIND SCENARIOS

APPENDIX B – PLOTS OF HIGH HYDRO CASE INTERFACE FLOWS WITH WIND SCENARIOS

APPENDIX C – COMPARISON OF LOW AND HIGH HYDRO GENERATION

APPENDIX D - GRIDVIEW INFORMATION

1. INTRODUCTION

This report documents the status of results for Task 1 of the Dakotas Wind Transmission Study. For Task 1, ABB is using the GridView program to simulate the system conditions hourly for a one year period and compare the availability of non-firm transmission to export this power from the Dakotas. Seven wind sites are being analyzed and from these seven sites eight scenarios have been developed. The scenarios are listed below.

Scenario 1: 500 MW at the Garrison 230-kV bus
Scenario 2: 500 MW at a new substation on the Leland Olds-Groton 345-kV line near Ellendale (Note: this Scenario is also referred to as Leland in some plots and tables)
Scenario 3: 500 MW at Pickert 230-kV bus
Scenario 4: 500 MW at the New Underwood 230-kV bus
Scenario 5: 500 MW at the Mission 115-kV bus (Without extensive upgrades to Ft. Randal this site will not accommodate 500 MW so a lower MW may be used)
Scenario 6: 500 MW at the Ft. Thompson 230-kV bus
Scenario 7: 500 MW at the White 345-kV bus
Scenario 8: 50 MW at each of the 4 previous sites in Scenarios 1 through 7 and 100 MW at 3 sites.

The location of these sites are shown in Figure 1.1 below.

GridView was set up to monitor the flows in the following three transmission interfaces:

- The North Dakota Export (NDEX) Interface
- Each of the two 230-kV lines from Watertown to Granite Falls
- The seven transmission lines from Ft. Thompson going east and southeast plus the 115-kV line from Bonesteel to Ft. Randall.

The locations of these transmission interfaces are shown in Figure 1.2 below.

The object of Task 1 of the Dakotas Wind Transmission Study is:

- Determine the potential wind generation of up to 500 MW of installed wind generators at each of the seven sites.
- Determine the ability of non-firm capacity on the existing transmission system to transfer new wind power throughout the year and identify the duration and levels of transmission constraints.

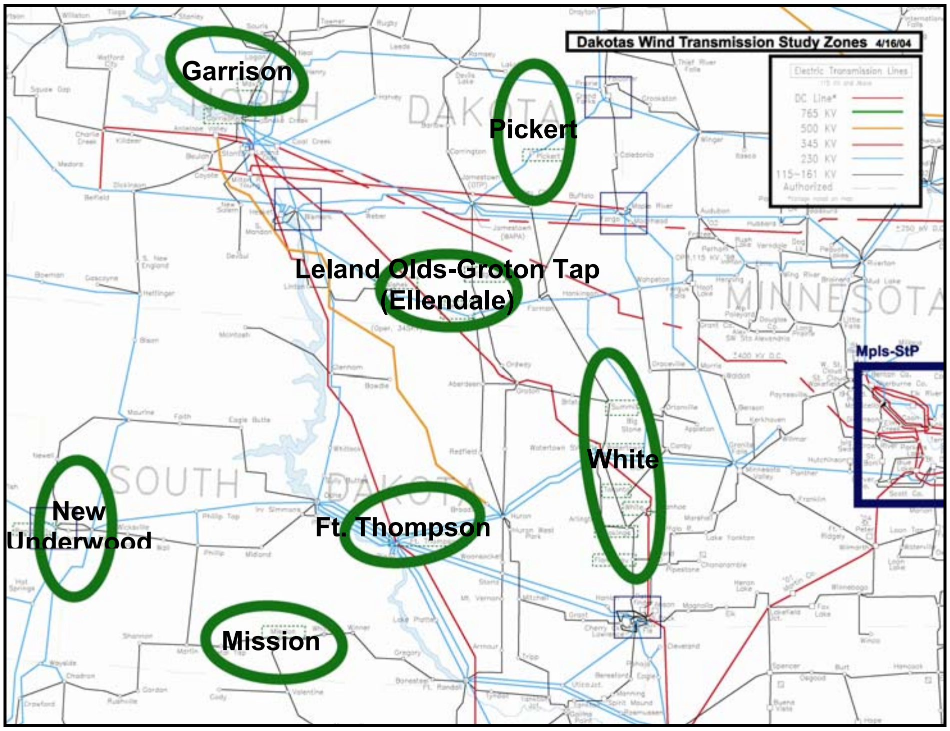


Figure 1.1 Seven Wind Sites Considered in the Study

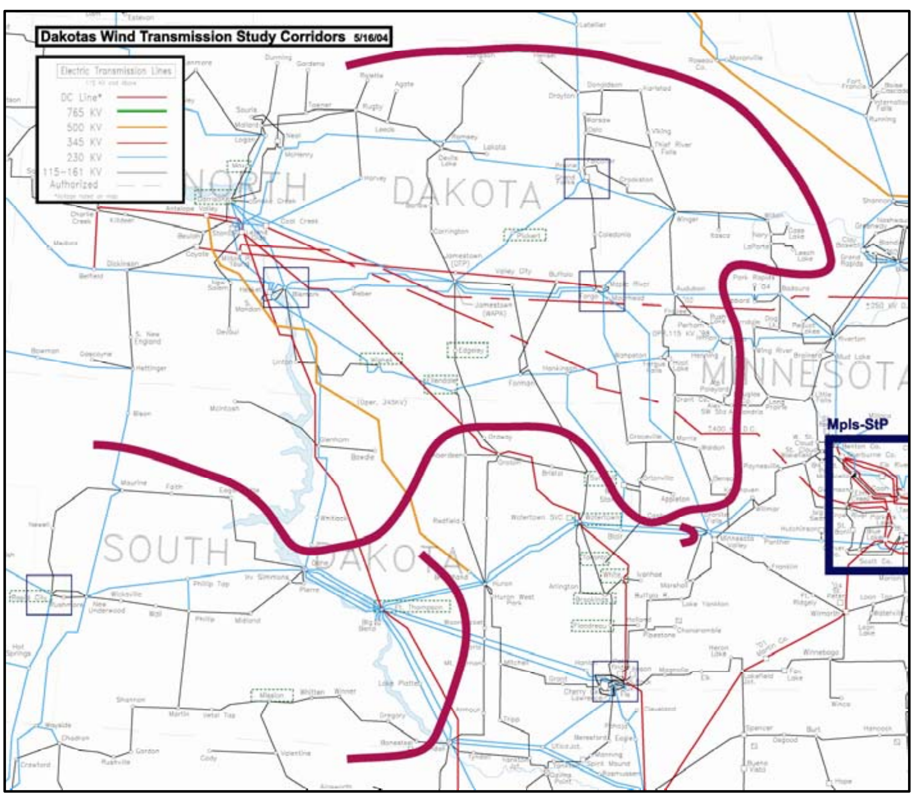


Figure 1.2 Three Transmission Interfaces Considered in the Study

2. DEVELOP HOURLY WIND GENERATION

2.1 Description of Method for Developing Hourly Wind Generation

This task developed the hourly generation for each of the seven sites for the historical year 2003 and data for a typical year. The first stage of site selection was based on publicly available wind resource maps of the Dakotas produced by NREL. The maps were imported into a GIS and combined with other information such as the existing transmission grid, roads, and population centers. Parks, national forests, and other environmentally and culturally sensitive areas were excluded from consideration. New wind resource maps of each selected site were generated using AWS Truewind's MesoMap system. The data was produced for an appropriate turbine hub height with 200-meter grid spacing, and was validated using available on-site and off-site wind data. Each region was set up with sub-regions and sub-regions were added until there was over 500 MW of installed capacity which resulted in sites having 500 MW to 600 MW of installed wind generation.

The simulations resulted in a set of 8760 hourly historical wind speed and direction values at the turbine hub height for any point in the region where a wind plant might be developed. The data reproduce correlations between project sites caused by regional and local weather patterns, and thus captured the benefits of geographic diversity in reducing aggregate wind plant output variability over the entire grid. For each site, the mean speed was scaled to match estimates of the average speed derived from onsite data and from the wind resource maps. Using a generic power curve for a large, state-of-the-art wind turbine, including expected plant and wake losses, the process converted the wind speed values to a time series of wind plant generation for several assumed plant sizes ranging from 50 to 500 MW. A weighted moving-average filter was applied to simulate the effect of aggregating the output of individual turbines within a plant. A summation of the simulation steps involved are:

1. Extract hourly speed and temperature data for each site from mesoscale runs – 8760 hours from 2003 and 8760 hours from 1984 to 1998
2. Validate and adjust diurnal speed patterns
3. Convert speed and air density to output
4. Apply 14% losses
5. Scale output to rated capacity

2.2 Calculated Hourly Wind Generation

At each of the seven sites, the site was divided into smaller areas. Each site was divided into eight to ten areas for a total of 65 areas and 50 MW or more of wind

turbines were assumed installed in each area. The total generation for each area was then calculated.
An example of one of the wind site outputs calculated for 2003 for 500 MW of installed wind is shown in Figure 2.2.1 for the Garrison Site.

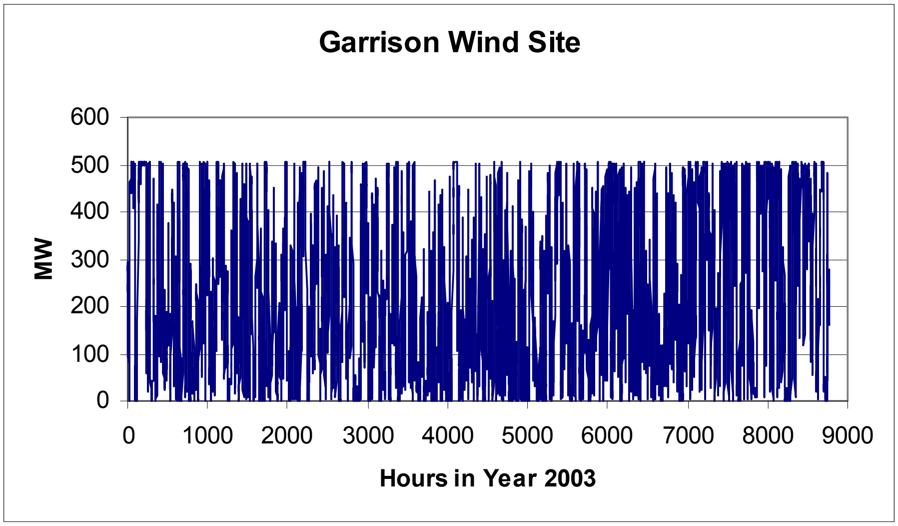


Figure 2.2.1 – 2003 Calculated Wind Generation At the Garrison Site

To get an idea of how this generation varies, a two week period at the end of June is shown in the graph in Figure 2.2.2 below.

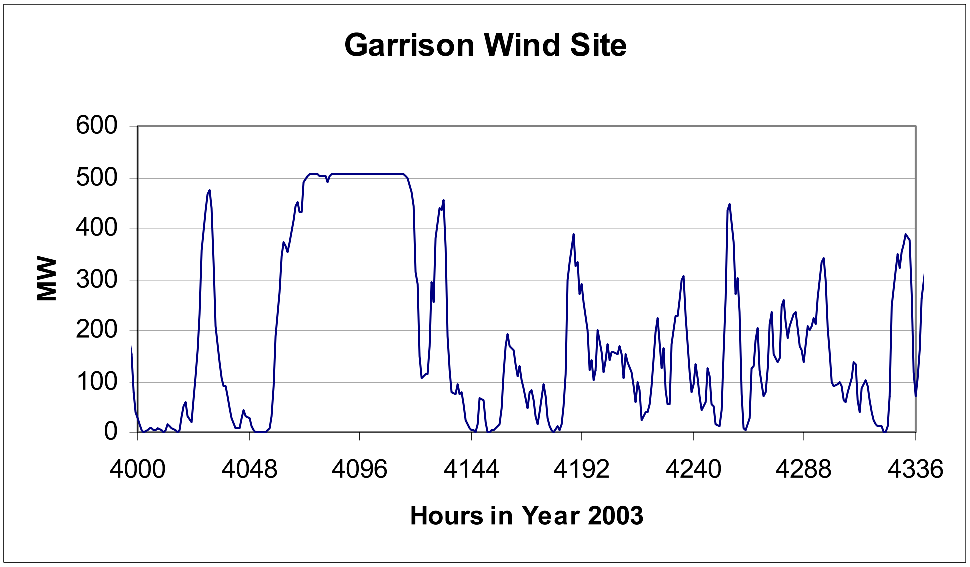


Figure 2.2.2 – June 2003 Calculated Wind Generation At the Garrison Site

These graphs are typical of the wind generation calculations for each of the seven sites. The generation continuously varies between minimum and maximum generation levels.

The installed turbine generation and the generation plant factor calculated for 2003 for each site are shown in Table 2.2.1 below. The generation was developed by subdividing each site. A typical configuration of wind turbines was developed in each sub-region and each site was developed to insure that at least 500 MW was installed. The total of all the sub-regions for most sites is above 500 MW and the Table 2.2.1 shows the installed capacity developed at each site.

Table 2.2.1
Installed Capacity and 2003 Calculated Plant Factor for the 7 Sites

Site	Installed Capacity	Plant Factor
1 GARRISON	618.1	38%
2 ELLENDALE	565.5	38%
3 PICKERT	543.5	36%
4 UNDERWOOD	525.2	33%
5 MISSION	531.1	39%
6 FT THOMPSON	511	38%
7 WHITE	522.1	40%

The installed turbine generation and the generation plant factor calculated for a typical year for each site are shown in Table 2.2.2 below. These values are all within one percent of the values calculated for 2003.

Table 2.2.2
Installed Capacity and TYPICAL YEAR Calculated Plant Factor for the 7 Sites

Site	Installed Capacity	Plant Factor
1 GARRISON	618.1	37
2 ELLENDALE	565.5	39
3 PICKERT	543.5	35
4 UNDERWOOD	525.2	33
5 MISSION	531.1	39
6 FT THOMPSON	511	38
7 WHITE	522.1	40

Some wind information for the typical year calculations are shown below. The 24 hour average output from each site for a typical year is shown in a series of plots in increments of two months in Figures 2.1.3A to 2.1.3.F below. Plotting the 24 hour average power production from each site shows a strong correlation between the sites. These plots are a 24-hour moving average.

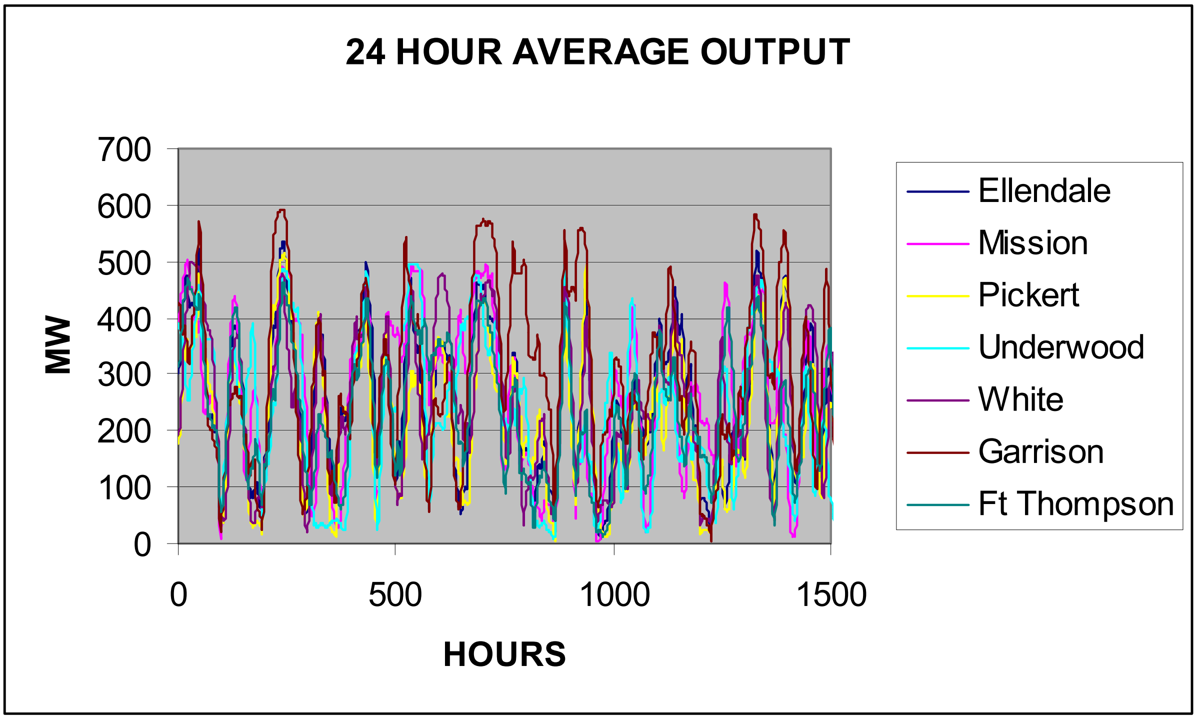


Figure 2.2.3A – Typical Year 24 Hour Average Output – First 2 Months

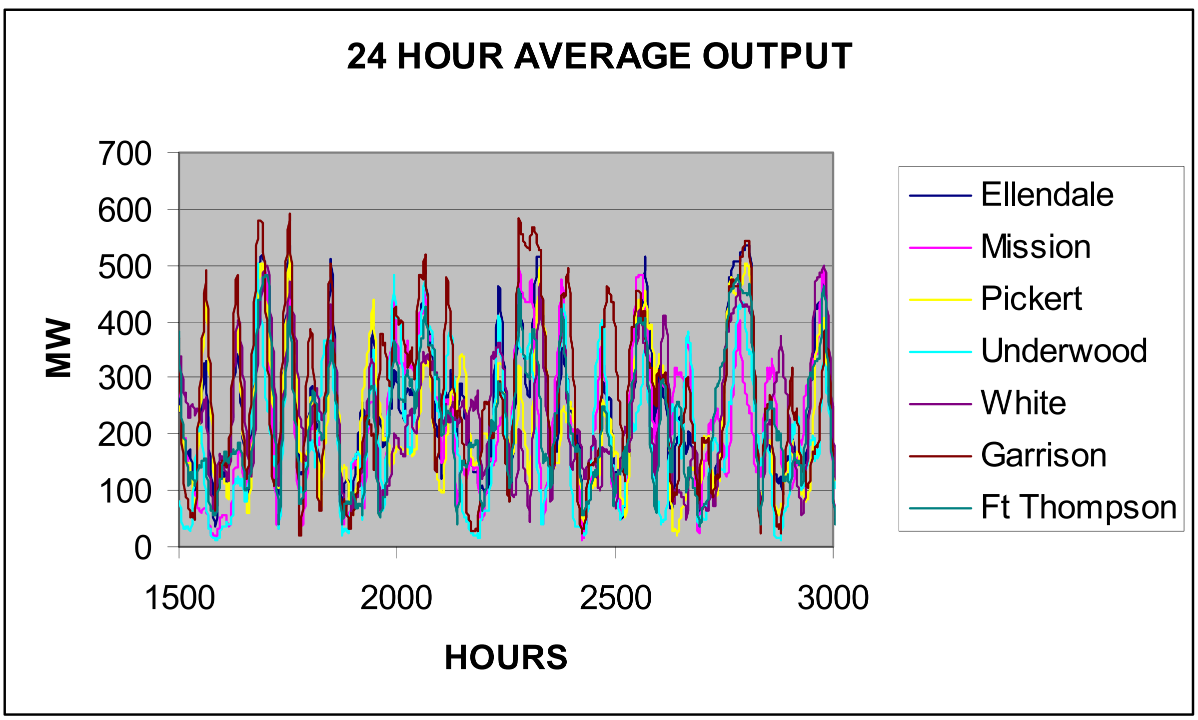


Figure 2.2.3B – Typical Year 24 Hour Average Output – Second 2 Months

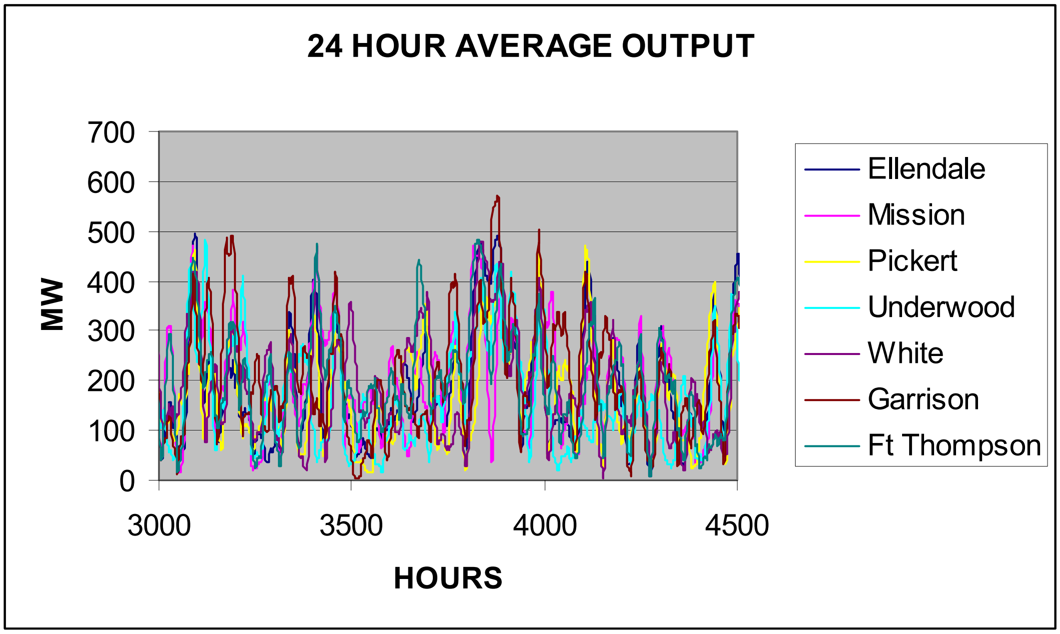


Figure 2.2.3C – Typical Year 24 Hour Average Output – Third 2 Months

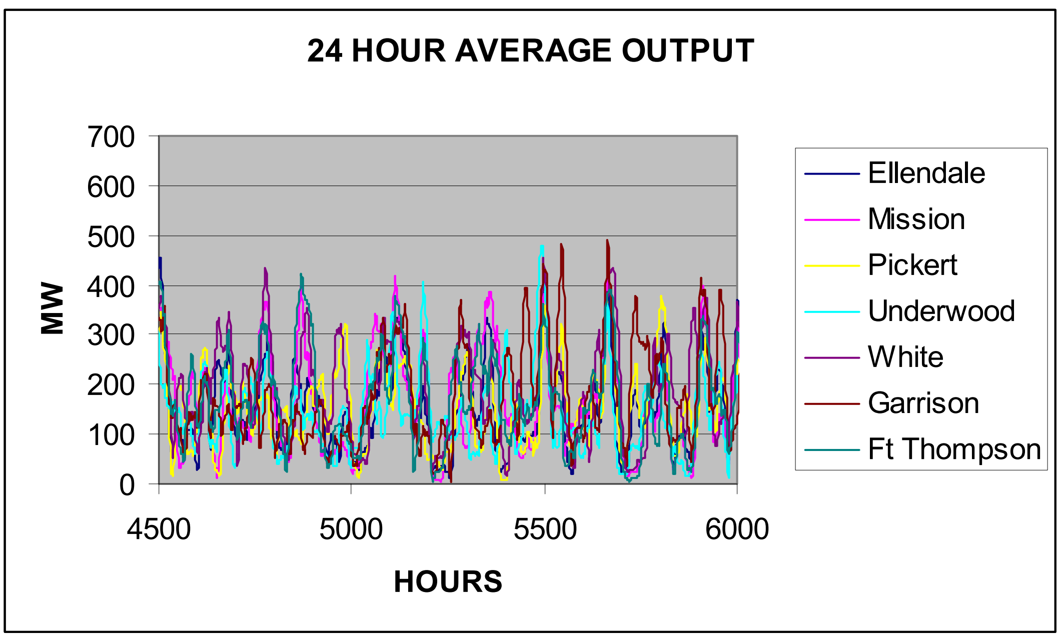


Figure 2.2.3D – Typical Year 24 Hour Average Output – Fourth 2 Months

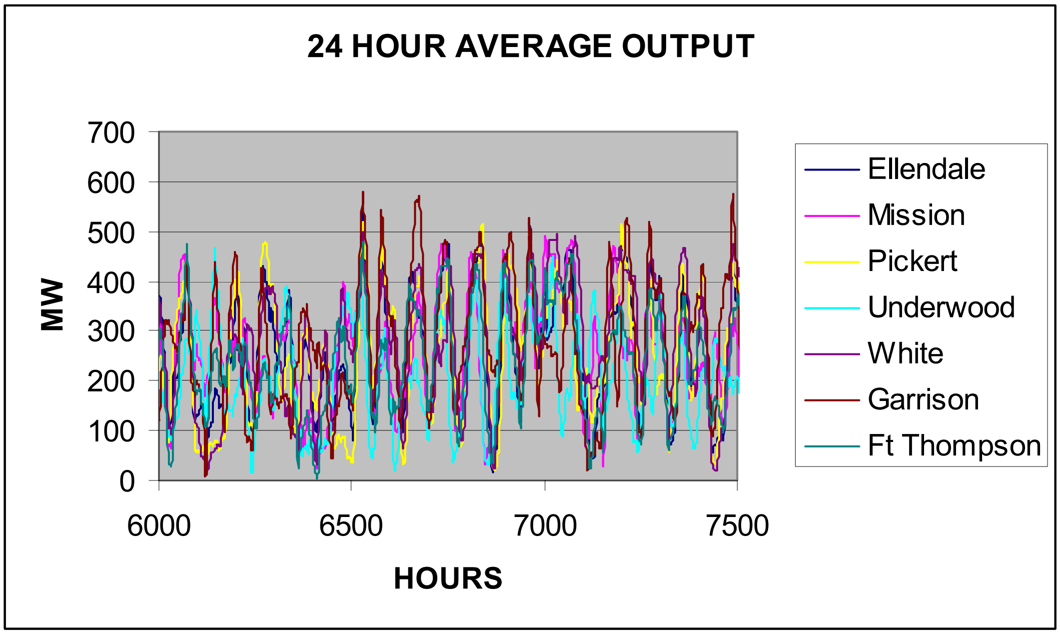


Figure 2.2.3E – Typical Year 24 Hour Average Output –Fifth 2 Months

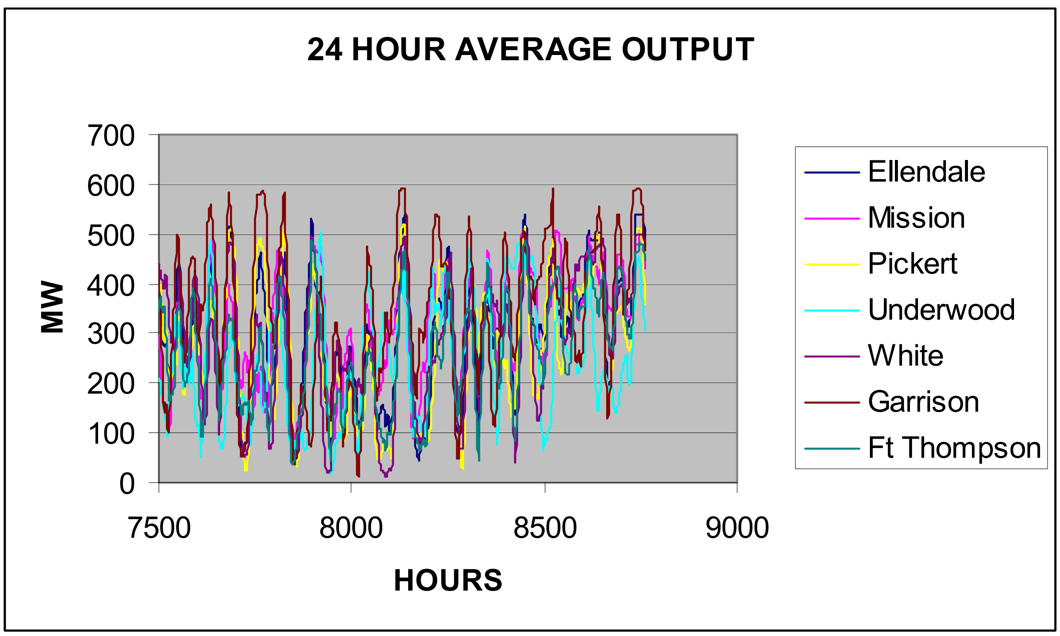


Figure 2.2.3F – Typical Year 24 Hour Average Output – Sixth 2 Months

The previous plots of the 24 hour power production indicates that there are higher levels of generation during some parts of the year than during other parts. The average monthly power by site is presented in Figure 2.2.4 for each site. The plot provide the per unit power but these values can also be considered the monthly generation plant factor for each site.

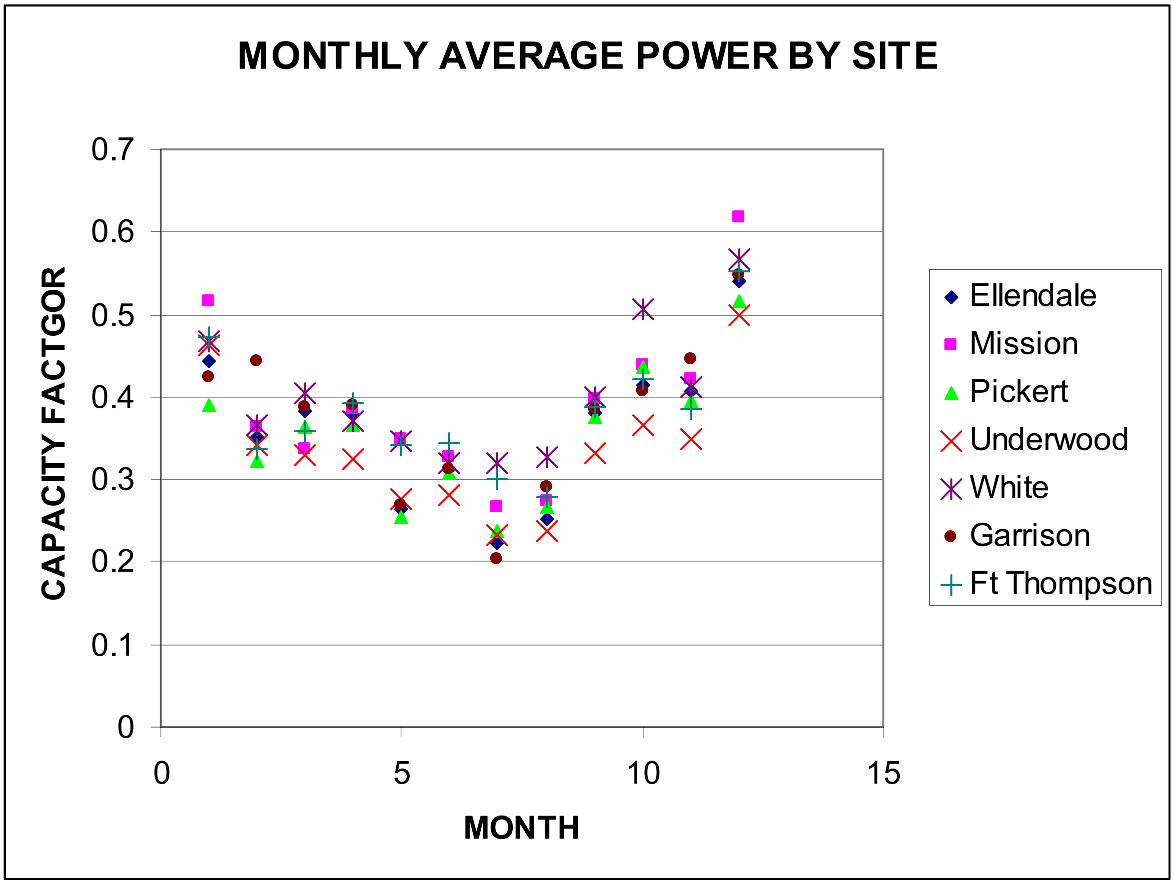


Figure 2.2.4 – Average Monthly Power at Each Site for the Typical Year Calculated Generation

Based on the above figure, the highest wind production is in December for all of the sites. The lowest wind production is in July. Even with the lowest production in July, Figures 2.2.1 and 2.2.2 indicate that the wind generation will still vary between maximum and minimum throughout the month, but the average generation will be lower in July.

3. DEVELOP GRIDVIEW DATABASE FOR HISTORICAL 2003 YEAR

GridView was set up to monitor the flows in the following three corridors:

- The North Dakota Export (NDEX) Interface
- Each of the 230-kV lines from Watertown to Granite Falls
- The seven transmission lines from Ft. Thompson going east and southeast plus the 115-kV line from Bonesteel to Ft. Randall.

GridView benchmarked the historical year by running a powerflow for each hour of 2003 and then comparing the monitored results of each of the three corridors against the actual use across each corridor using recorded historical data.

The historical data was provided by WAPA in three databases. The first data set contained the measured half-hour power flow for 2003 on all of the lines comprising the three interfaces defined for the study and all of the measured half-hour generation for 2003 for the large coal and hydro generation in North Dakota. The second submittal contained all of the hourly hydro generation in the Dakotas for the years 1997 and 2003. The third data submittal included the Miles City HVDC transfers and the flows on the Tioga-Boundary line for 1997 and 2003.

This data was used to develop the GridView data base to represent the actual 2003 system conditions and power transfers.

To benchmark the GridView data, the interface flows calculated in GridView were compared to the measured flows for the historical year 2003. The benchmark results from the GridView simulation of the MAPP system for the year 2003 correlate with the measured data. The following assumptions were made for the GridView study.

Assumptions:
The 2013 database developed for previous MAPP regional studies was used as a starting point with the following changes.

- The WAPA loads for 2003 were provided by WAPA. This covers most of the North Dakota loads and all of the South Dakota loads. The Otter Tail loads were based on 2003 load shape data and they represent the remaining loads in North Dakota.
- Generation dispatch in North Dakota was based on the 2003 recorded data.
- WAPA dispatched hydro generation was based on the 2003 recorded data.
- Miles City DC interconnection and Tioga Falls interconnection modeled using actual 2003 data supplied by WAPA
- Sidney and Stegall DC interconnections modeled as fixed flows of 200MW and 110MW respectively from East to West
- Rapid City DC was not in service for 2003
- The data was developed in November 2004 and an NDEX limit of 1950 MW was identified as the limit to monitor in the study.

Figure 3.1 and 3.2 show the actual metered and GridView simulated flows respectively on the NDEX interface for the year 2003. It can be observed from these two figures that the simulation results match the actual flows to a large extent. The difference between the measured and GridView calculated NDEX flows are shown in Figure 3.3. In Figure 3.3 the average difference for the year is 6.6 MW, the average deviation from this value is 2 MW, and the peak differences are +71.9 MW and –81.4 MW.

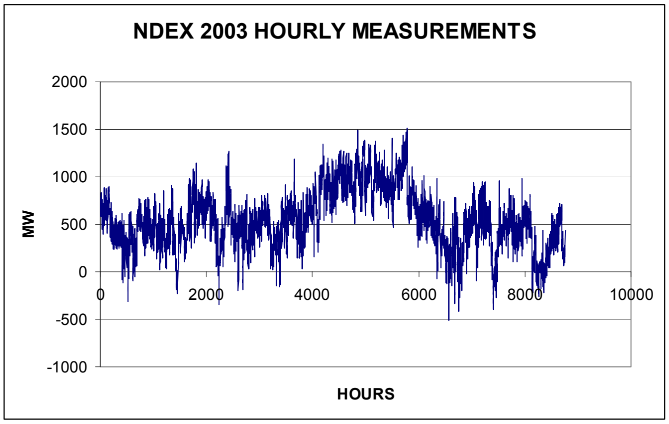


Figure 3.1 NDEX flows for 2003 from Telemetry Data

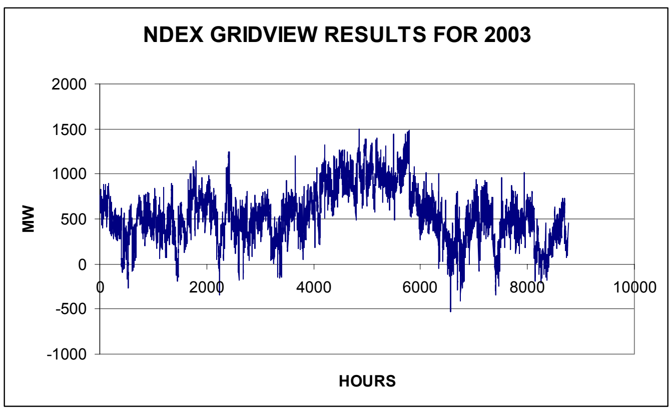


Figure 3.2 NDEX flows for 2003 from GridView Simulations

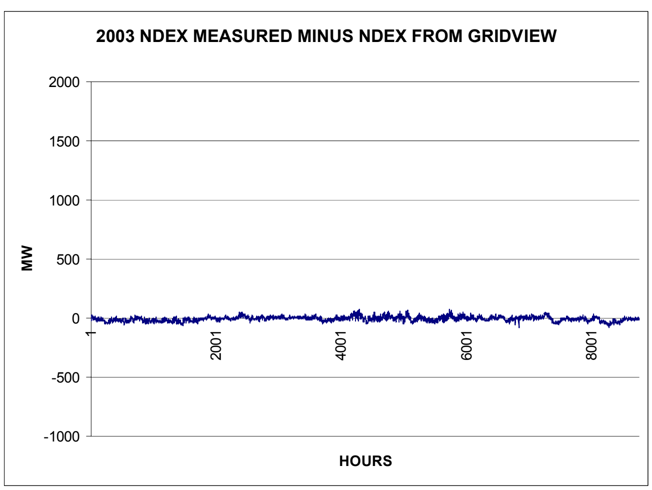


Figure 3.3 Measured NDEX Flows Minus GridView NDEX Flows

Figure 3.4 and 3.5 show the actual metered and GridView simulated flows respectively on the Ft. Thompson interface for the year 2003. It can be observed from these two figures that the simulation results match the actual flows to a large extent. The difference between the measured and GridView calculated Ft. Thompson flows are shown in Figure 3.6. In Figure 3.6 the average difference for the year is 10.2 MW, the average deviation from this value is 2 MW, and the peak differences are +77.3 MW and –73.9 MW.

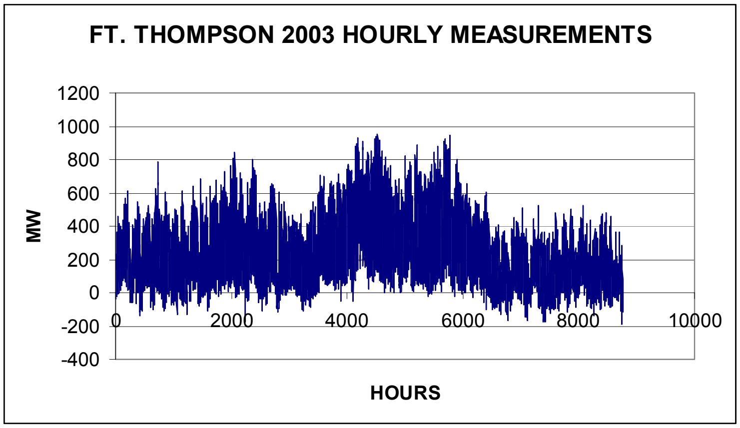


Figure 3.4 Ft. Thomson flows for 2003 from Telemetry Data

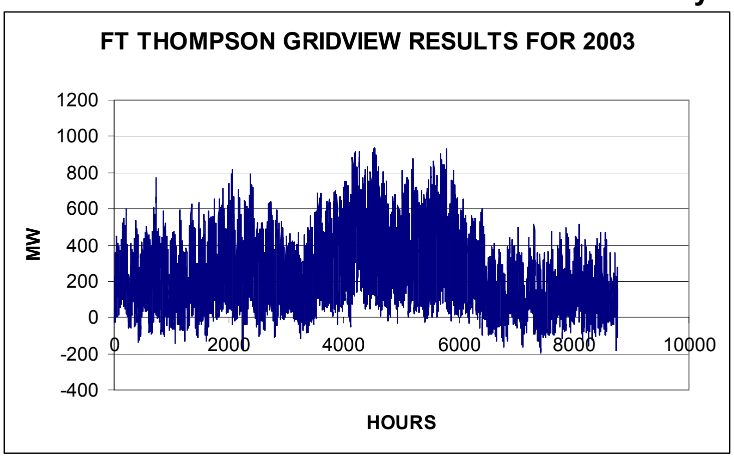


Figure 3.5 GridView Simulation of Ft. Thomson Flow

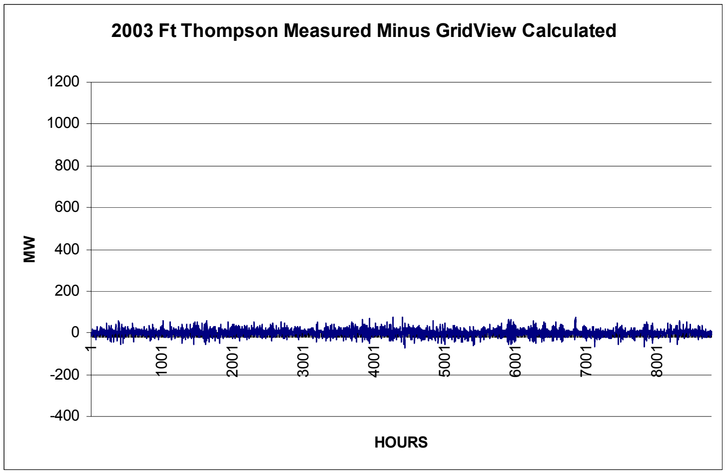


Figure 3.6 Measured Ft. Thomson Flows Minus GridView Ft. Thomson Flows

Figure 3.7 and 3.8 show the actual metered and GridView simulated flows respectively on the Watertown interface for the year 2003. This interface was defined as being at the Granite Falls end of the two Watertown-Granite Falls 230-kV lines, but the actual measurements provided were taken at the Watertown end so GridView monitored the lines also at the Watertown end.

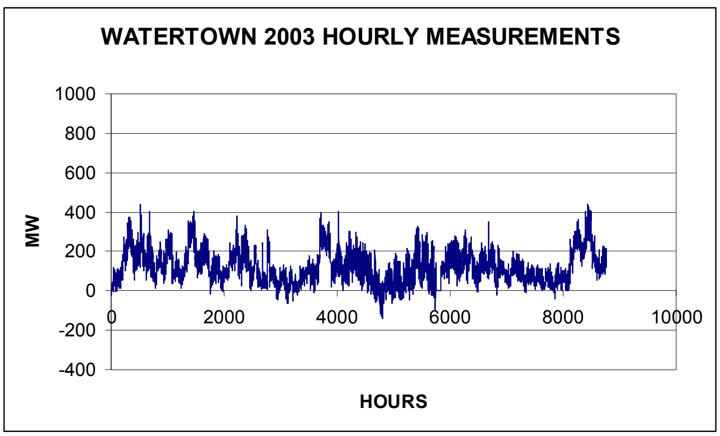


Figure 3.7 Watertown flows for 2003 from Telemetry Data

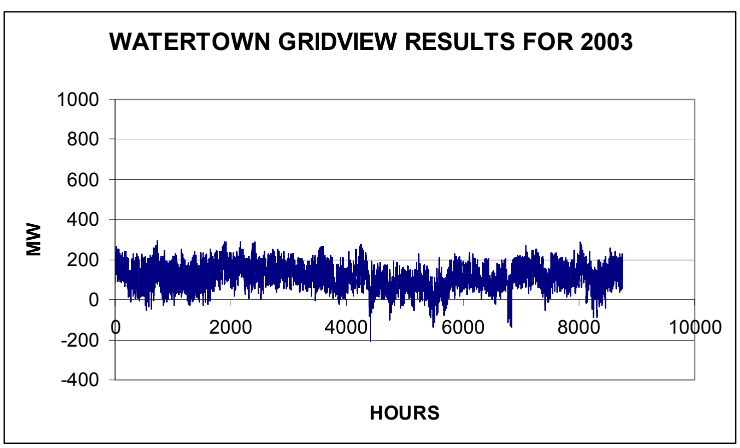


Figure 3.8 GridView Simulation of Watertown Flow

It can be observed from these two figures that the measured and GridView simulation results vary. The measured levels generally vary between zero and 400 MW while the GridView results generally vary between zero and 200 MW. The Big Stone generating unit has the largest impact on the Watertown flows. The actual output of this unit was not included with the measured data provided by WAPA. Since it is a coal unit, it was dispatched in Gridview as a base load unit which was on at rated output throughout the GridView simulations. When the Big Stone unit output is reduced, flows measured at Watertown on the interface are increased. If Big Stone not generating power the flow on the Watertown interface increases about 200 MW. Those periods on the measured Watertown interface where the flows go over 200 MW are probably due to Big Stone output being reduced or even off.

Also the generation in Minnesota was dispatched automatically by GridView. The dispatch of Minnesota generation will impact the flows on the Watertown interface. Since the Minnesota Gridview dispatch is not the actual 2003 dispatch, this difference in generation patterns in Minnesota will also impact the comparison of the actual versus simulated Watertown interface. Below is the difference between the actual measured Watertown interface and the Gridview results. These differences highlight the impact of the Big Stone generation and the Minnesota generation on this interface.

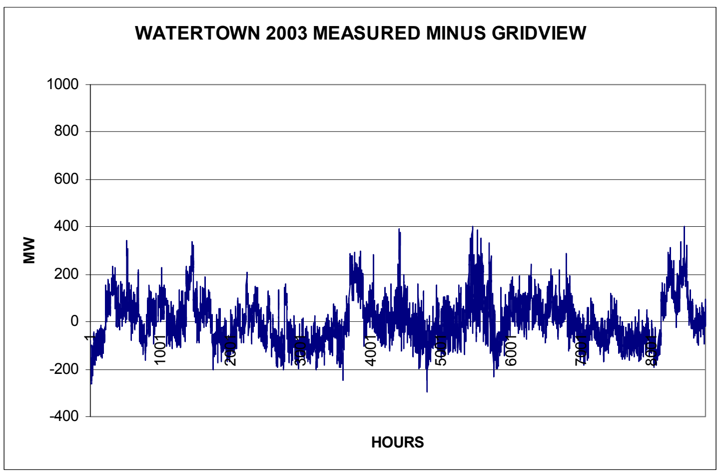


Figure 3.9 Measured Watertown Flows Minus GridView Watertown Flows

Overall, the NDEX and Ft. Thompson GridView results match the actual metered flows quite closely. The Watertown interface is the most difficult to match since it is impacted by generation outside of the Dakotas.

4. INTERFACE POWERFLOW RESULTS WITH WIND GENERATION

This section of the report presents selected results from the GridView simulations that were performed for the Dakotas Wind generation study. Two base cases were developed for this analysis, first the low hydro scenario based on the actual 2003 hydro generation, and second the high hydro scenario based on 1997 hydro generation levels. For each scenario, the impact of adding wind generation at the various identified wind sites was analyzed by calculating the flows. The number of hours the flow is limited by interface constraints is determined.

Plots of the three interface flows for all of the wind scenarios for the 2003 low hydro case are included in Appendix A and plots of the three interface flows for all of the wind scenarios for the high hydro case are included in Appendix B.

4.1 2003 Low Hydro GridView Results

Table 4.1.1 shows the average flow on the three defined interfaces for the low hydro scenarios. The average flow on NDEX increases most for the wind sites that are inside this interface (Garrison, Ellendale, and Pickert). Similarly, the average flow on the Ft. Thomson interface increases most when the wind generation is at this location. For the Watertown interface, the flow increases most for the White wind site which is the closest site to the Watertown interface.

Table 4.1.1 Average Interfaces Flows For The Low Hydro Scenarios

Interface Name	Base Case	Garrison	Ellendale	Pickert	Underwood	Mission	Ft Thompson	White
	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(MW)
NDEX	584	818	768	799	576	563	565	562
Ft. Thompson	289	353	341	330	381	398	463	286
Watertown	220	235	240	212	239	241	247	273

The table below shows what percentage of the power from each wind site flows through each interface.

Table 4.1.2 Power Flow Interface Distribution by Site

Power Distribution Through the Interface			
Site	NDEX	Ft Thompson	Watertown
Garrison	100%	23%	12%
Mission	0%	46%	17%
Underwood	0%	45%	17%
Ft. Thomson	0%	79%	20%
White	0%	-2%	28%
Pickert	100%	16%	5%
Ellendale	100%	24%	16%

The results of the cases are plotted in Appendix A, but several cases are highlighted in the plots below. Since Table 4.1.1 shows that the wind power generated at the Garrison site will have the most flow through the NDEX interface, Figure 4.1.1 is a plot of the NDEX interface with wind generation modeled at the Garrison site. The plot indicates that there is a few hours during the year when the interface flows will exceed the 1950 MW limit of the NDEX interface. The results for all sites are presented in Table 4.1.3.

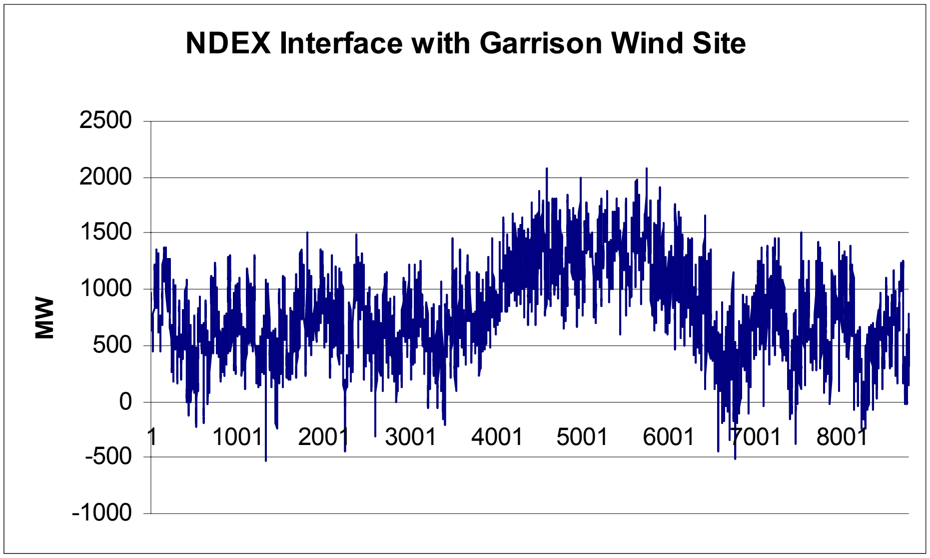


Figure 4.1.1 NDEX Interface Flows for the Garrison Wind Site

Table 4.1.1 indicates that the Ft. Thompson interface will be impacted the most by the Ft. Thompson wind site since most of the wind power generated will flow through the interface. Figure 4.1.2 is a plot of the Ft. Thompson interface with wind generation modeled at the Ft. Thompson site.

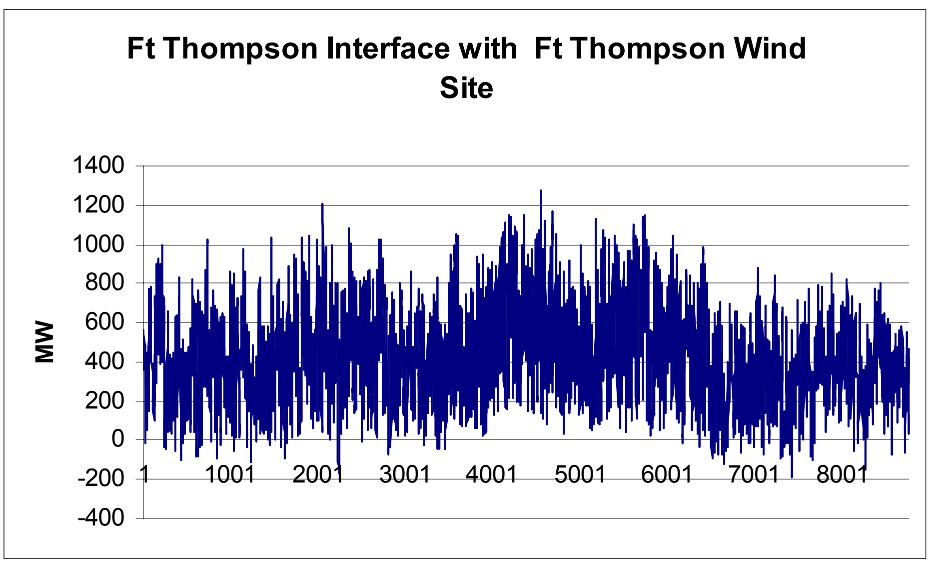


Figure 4.1.2 Ft. Thompson Interface Flows for the Ft. Thompson Wind Site

Table 4.1.1 indicates that the Watertown interface will be impacted the most by the White wind site since it transmits the most the wind power through the interface. Figure 4.1.3 is a plot of the Watertown interface with wind generation modeled at the White site.

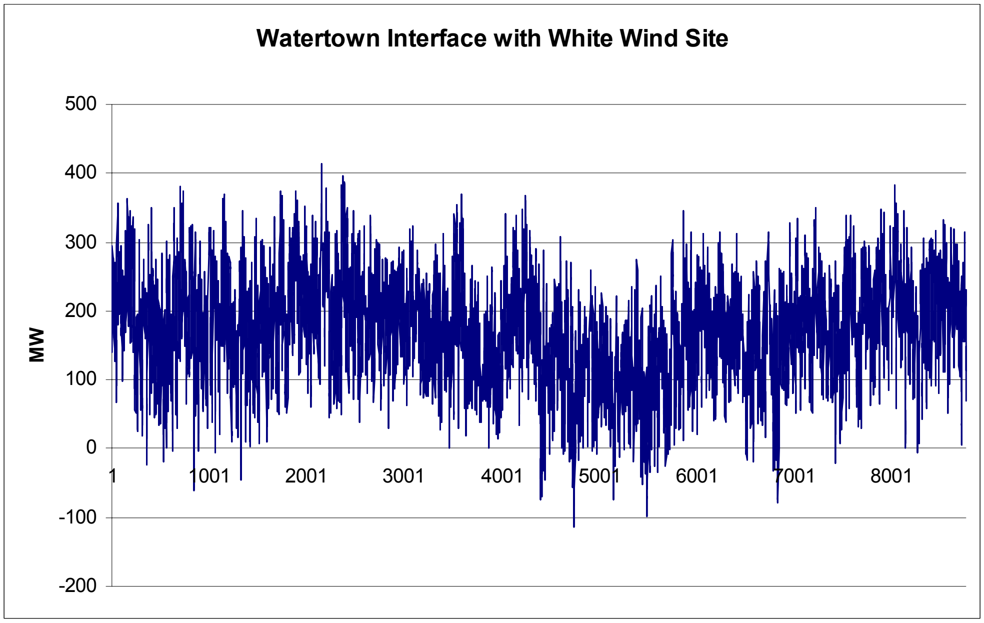


Figure 4.1.3 Watertown Interface Flows for the White Wind Site

Table 4.1.3 shows the number of hours during the year the three interfaces are limiting. The only limiting interface is NDEX.

Table 4.1.3 Interfaces Limits For The Low Hydro Scenarios

Interface	Flow/Limit Exceeded	Base Case	Garrison	Ellendale	Pickert	Underwood	Mission	Ft Thompson	White	All Sites
NDEX	Max Flow	1529	2085	2008	2002	1775	1771	1771	1774	1788
1950 MW Limit	Hours	0	14	3	9	0	0	0	0	0
	MWH	0	849	129	204	0	0	0	0	0
Ft. Thompson	Max Flow	953	1022	1022	1012	1137	1077	1272	938	1022
>1500 MW Limit	Hours	0	0	0	0	0	0	0	0	0
	MWH	0	0	0	0	0	0	0	0	0
Watertown	Max Flow	296	326	334	313	344	340	355	413	352
850 MW Limit	Hours	0	0	0	0	0	0	0	0	0
	MWH	0	0	0	0	0	0	0	0	0

From the simulation, it can be observed that NDEX is limiting, although only for a few hours during the year, for the three sites in North Dakota (Garrison, Ellendale, and Pickert). The number of hours of constrained operation indicates that the flowgates or interfaces do not significantly limit the operation of the wind generation at the proposed sites.

Based on this analysis, it was determined that NDEX was most limiting for the Garrison Scenario. For the Garrison site, the wind export was limited for 14 hours and 849 MWh was not dispatched due to this limit for the historical year 2003. This is less than 0.04% of the 2,290,749 MWh of wind generation at the Garrison site.

4.2 High Hydro GridView Results

The 2003 base case was a year of low hydro or low water conditions so this case was considered as the case for low hydro conditions. Data for the Dakota hydro plants was also provided for 1997 which was a year with high hydro or high water conditions. There was some missing data for 1997 and for the GridView simulations it was assumed that the missing data was typical to the same time period preceding the missing data. Appendix C has plots of the Garrison, Oahe, and Big Bend generation as follows:

- 2003 low hydro base case
- 1997 raw data with missing information
- 1997 data used in the Gridview simulations

Figure 4.2.1 below is a plot of the total 2003 generation for Garrison, Oahe, and Big Bend representing a low hydro case. This can be compared to Figure 4.2.2 below which is a plot of the Garrison, Oahe, and Big Bend generation used in the high hydro case and based on the 1997 generation.

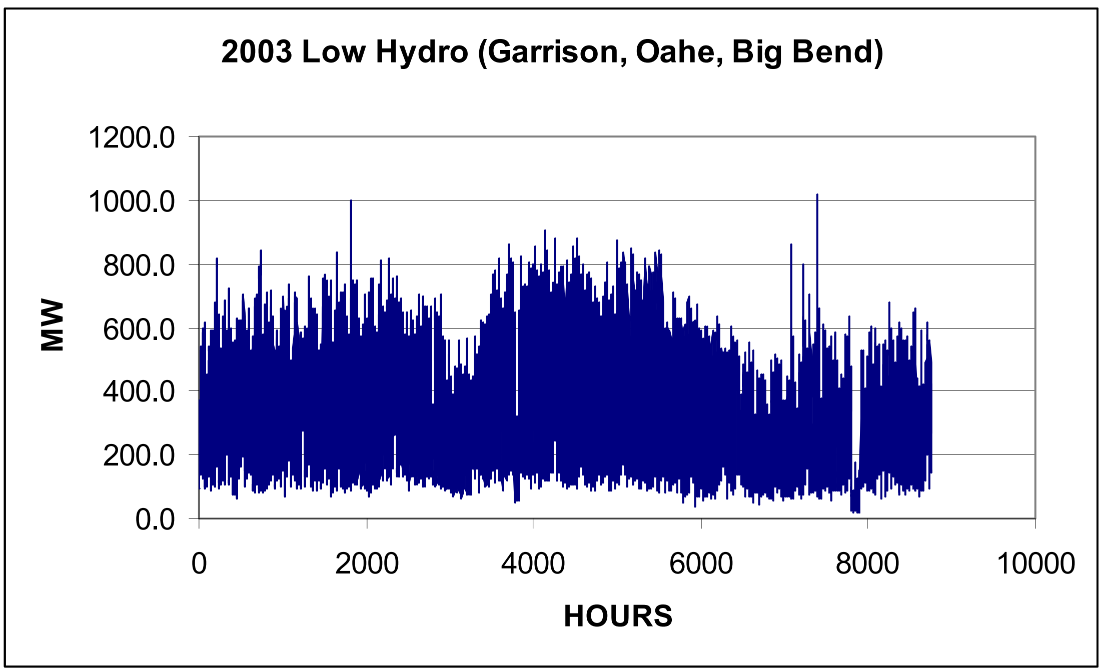


Figure 4.2.1 Garrison, Oahe, and Big Bend 2003 Low Hydro Generation

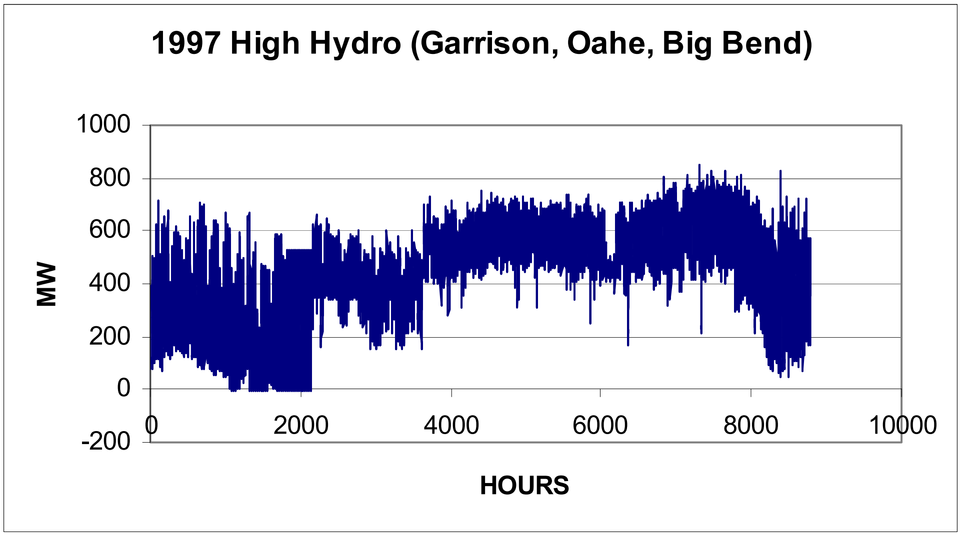


Figure 4.2.2 Garrison, Oahe, and Big Bend 1997 High Hydro Generation

General observations comparing Figures 4.2.1 and 4.2.2 indicate that although the average generation is higher for the high hydro case in 1997, the peak generation is often higher in the 2003 low hydro case. This may result in the peak interface flows being lower in the high hydro case than in the low hydro cases.

The complete GridView results of the high hydro cases are plotted in Appendix B, but several cases are highlighted in the plots below. Since Table 4.1.1 shows that the wind power generated at the Garrison site will have the most flow through the NDEX interface, Figure 4.2.3 is a plot of the NDEX interface with wind generation modeled at the Garrison site. The plot indicates that thereare few hours during the year when the interface flows will exceed the 1950 MW limit of the NDEX interface. The results for all sites are presented in Table 4.2.1.

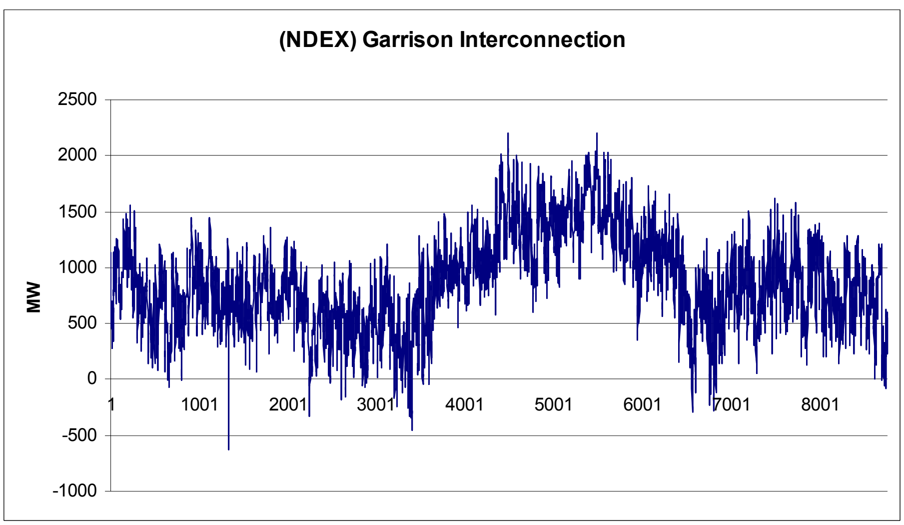


Figure 4.2.3 NDEX Interface Flows for the Garrison Wind Site with High Hydro

Table 4.1.1 indicates that the Ft. Thompson interface will be impacted the most by the Ft. Thompson wind site since most of the wind power generated will flow through the interface. Figure 4.2.4 is a plot of the Ft. Thompson interface with wind generation modeled at the Ft. Thompson site.

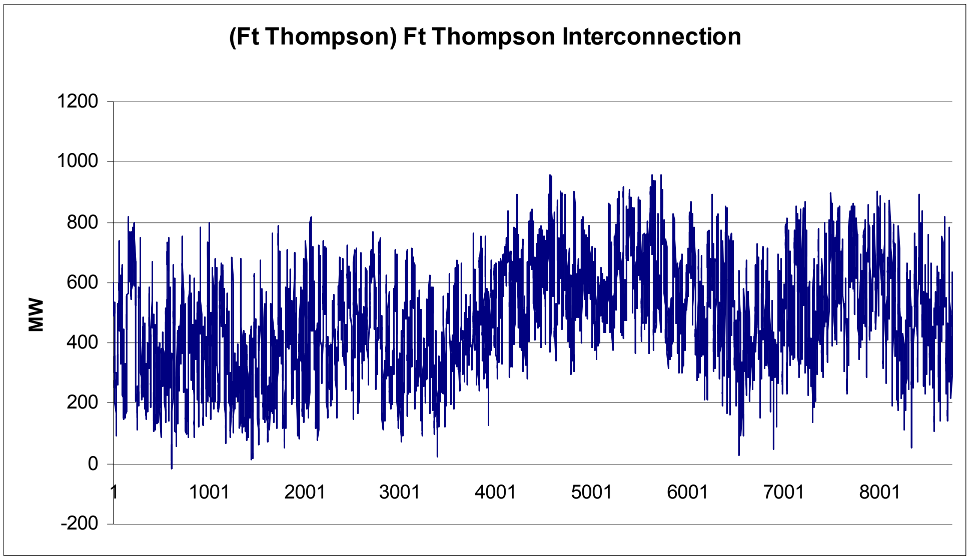


Figure 4.2.4 Ft. Thompson Interface Flows for the Ft. Thompson Wind Site with High Hydro

Table 4.1.1 indicates that the Watertown interface will be impacted the most by the White wind site since it transmits the most the wind power through the interface. Figure 4.2.5 is a plot of the Watertown interface with wind generation modeled at the White site.

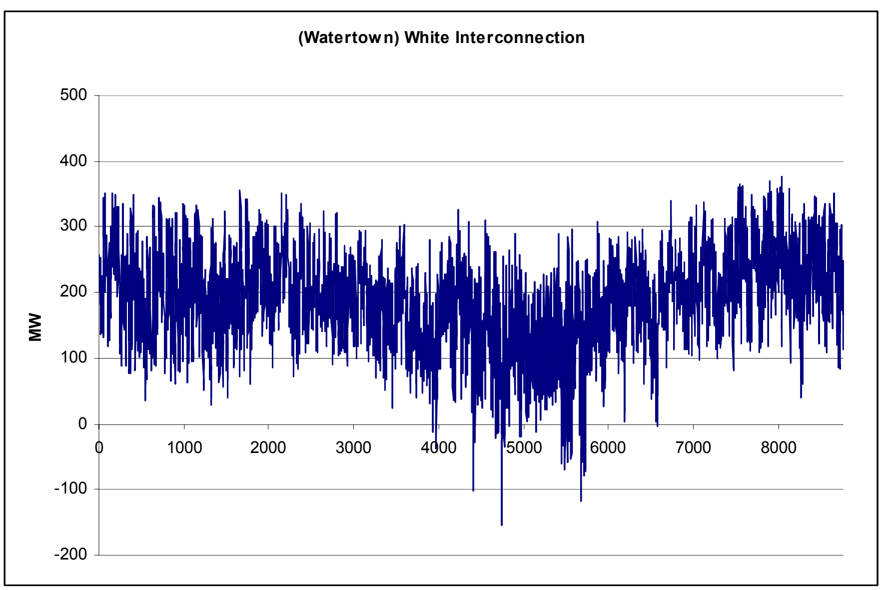


Figure 4.2.5 Watertown Interface Flows for the White Wind Site with High Hydro

Table 4.2.1 shows the number of hours during the year the three interfaces are limiting for the high hydro conditions.

Table 4.2.1 Interfaces Limits For The High Hydro Scenarios

Interface	Flow/Limit Exceeded	Base Case	Garrison	Ellendale	Pickert	Underwood	Mission	Ft Thompson	White	All Sites
NDEX	Max Flow	1725	2205	1977	1947	1716	1721	1721	1723	1806
1950 MW Limit	Hours	0	32	2	0	0	0	0	0	0
	MWH	0	2256	45	0	0	0	0	0	0
Ft. Thompson	Max Flow	660	750	695	695	815	833	958	658	757
>1500 MW Limit	Hours	0	0	0	0	0	0	0	0	0
	MWH	0	0	0	0	0	0	0	0	0
Watertown	Max Flow	285	311	313	281	305	307	325	376	314
850 MW Limit	Hours	0	0	0	0	0	0	0	0	0
	MWH	0	0	0	0	0	0	0	0	0

From the simulation, it can be observed that NDEX is limiting for only for a few hours during the year, for two of the three sites in North Dakota (Garrison and Ellendale). The number of hours of constrained operation indicates that the flowgates or interfaces do not significantly limit the operation of the wind generation at the proposed sites.

Based on this analysis, it was determined that NDEX was most limiting for the Garrison Scenario. For the Garrison site, the wind export was limited for 32 hours and 2256 MWh was not dispatched due to this limit for the high hydro year. This is less than 0.1% of the 2,290,749 MWh of wind generation at the Garrison site.

4.3 Summary of Results

For the conditioned modeled for the 2003 year and for the 1997 high hydro year model, up to 500 MW of wind could be installed at one of the seven sites with no significant amount of undelivered power. Of the three interfaces monitored, only NDEX reached its limit and the amount of wind power that would be curtailed was very small. The maximum loadings on each interface for the 2003 simulations are summarized below.

NDEX Interface was at 1950 MW for two sites:

- Garrison site was limited for 32 hours and 2256 MWH (less than 0.1%) was curtailed for the high hydro conditions and 14 hours and 849 MWH for 2003 low hydro conditions.
- Ellendale site was limited for 2 hours for high hydro and 3 hours for low hydro
- Pickert site was limited 9 hours for the low hydro case
- The South Dakota sites cause little increase in NDEX

Ft. Thompson Interface:

- The Ft. Thompson site causes the highest flows across the St. Thompson interface with the peak hour flow of 1272 MW and three hours during the year with flows above 1200 MW.
- The New Underwood site causes the second highest flows across the Ft. Thompson interface with the peak hour flow of 1137 MW and two hours during the year with flows above 1100 MW.
- All other sites resulted in less than 1100 MW across the Ft. Thompson interface.

Watertown Interface:

- The White site causes the highest flows across the Watertown interface with the peak hour flow of 413 MW and two hours during the year with flows above 400 MW.
- All other sites had only a few hours during the year that the Watertown interface flows exceeded 300 MW.

This study assumed an intact system will all lines in service. The main conclusion from this study is that under normal system intact conditions, non-firm transmission is available most of the time across the three monitored interfaces for up to 500 MW at any one of the seven wind sites studied. Long term transmission outages in the future could reduce the capability of power transfers across one of these interfaces for the duration of the outage. Future flows on the MAPP system and across these interfaces may also change as other generation and transmission projects are installed on the system and/or as the system dispatch philosophy are modified. Changes to the loading pattern and addition of other generation may impact the availability of non-firm transmission.

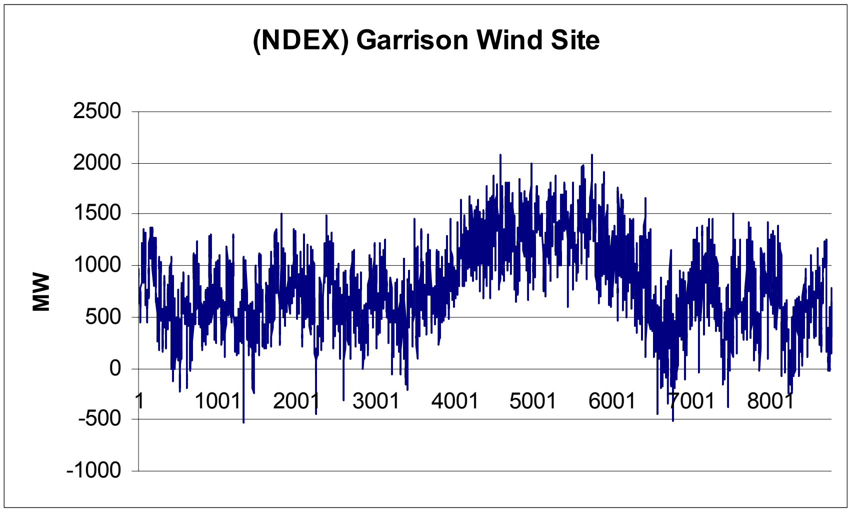
DAKOTA WIND TRANSMISSION STUDY

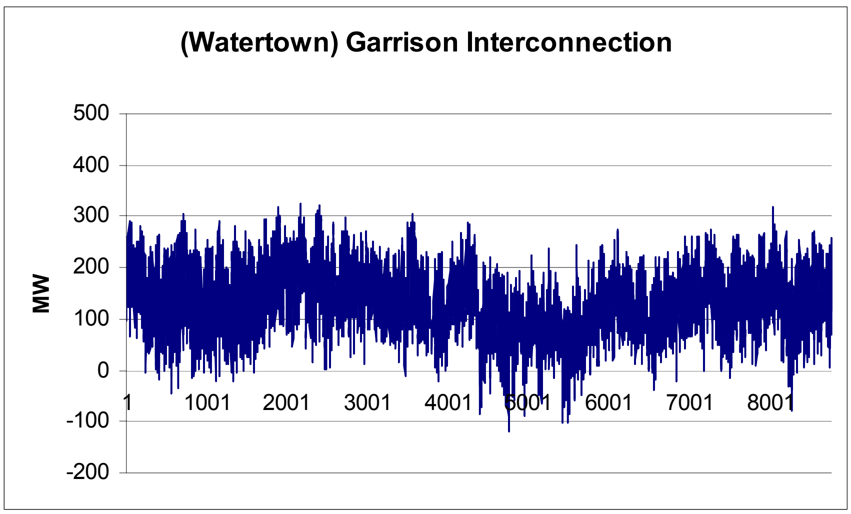
TASK 1
Non-Firm Transmission Potential to Deliver Wind Generation

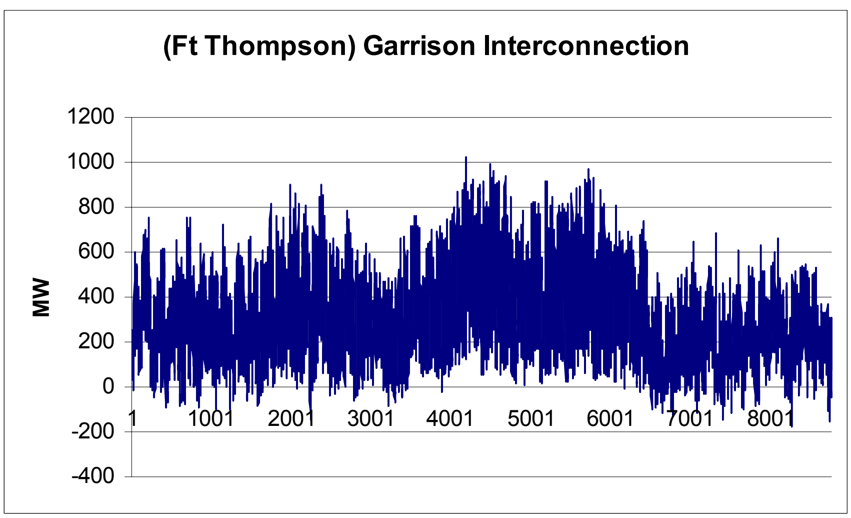
APPENDIX A

RESULTS FROM GRIDVIEW ON LOW HYDRO GENERATION

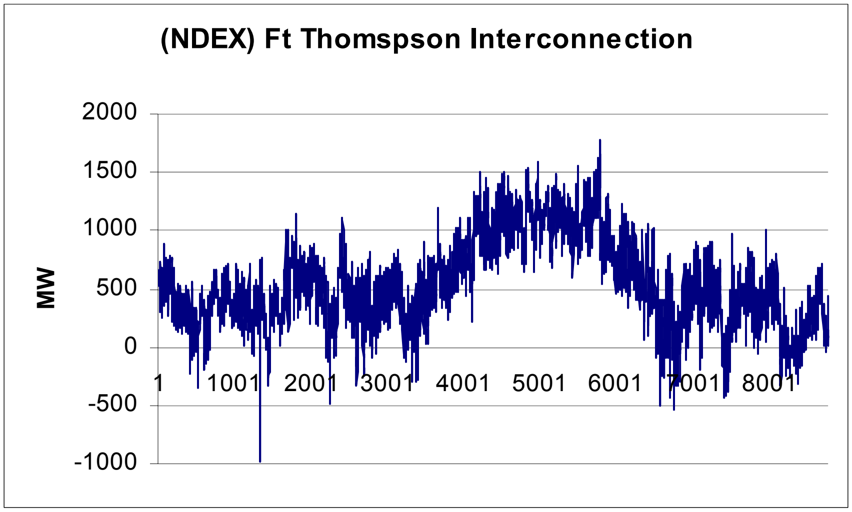
GARRISON SITE

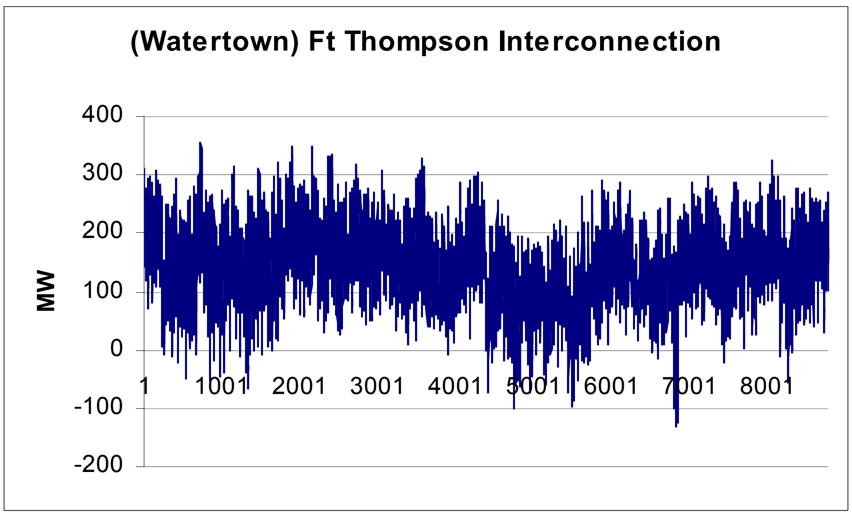


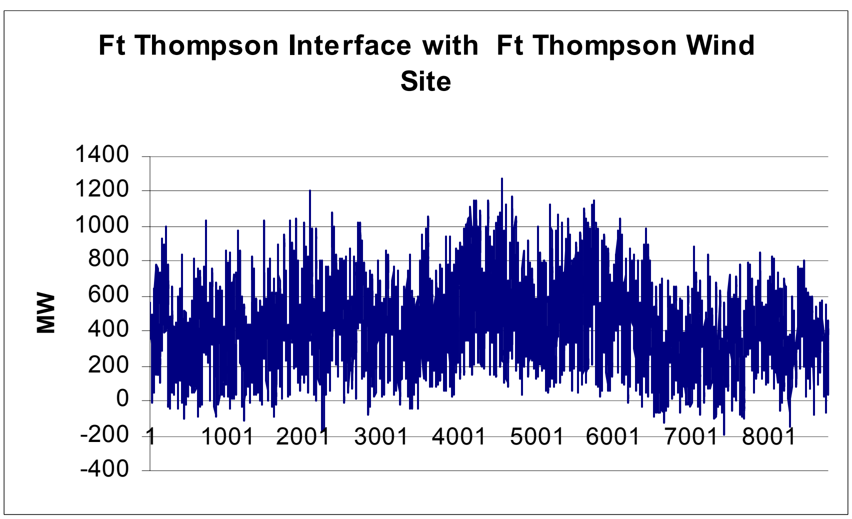




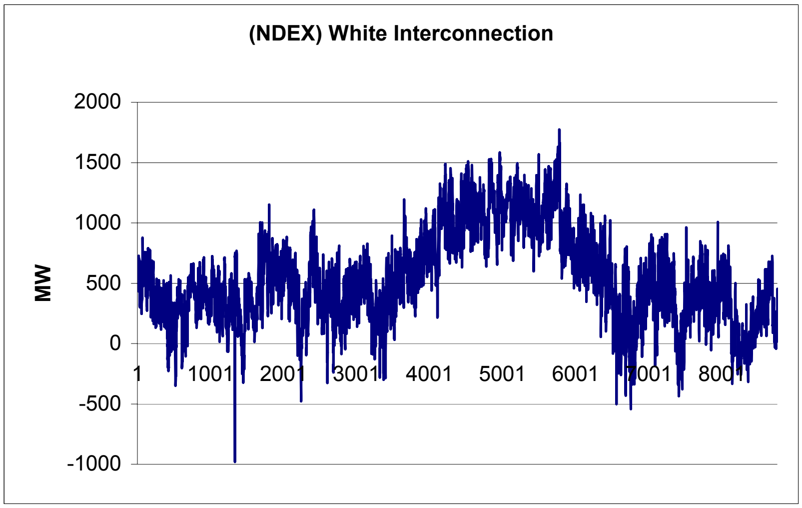
FT. THOMPSON SITE







WHITE SITE


(NDEX) White Interconnection
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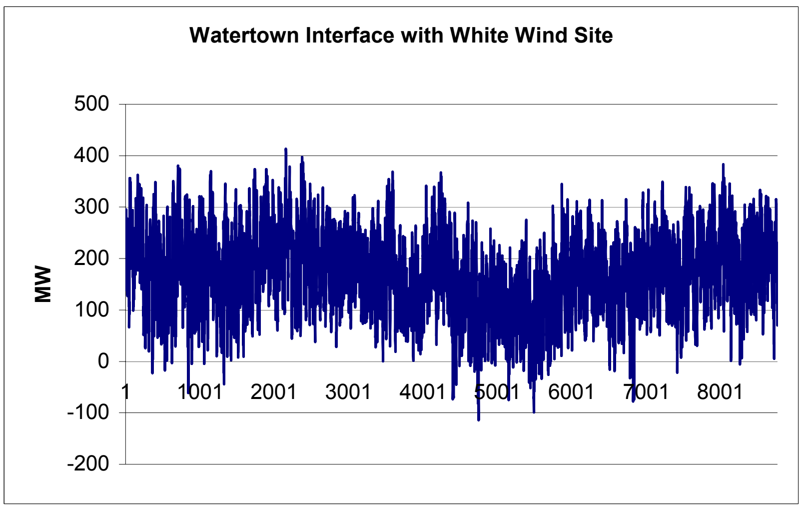
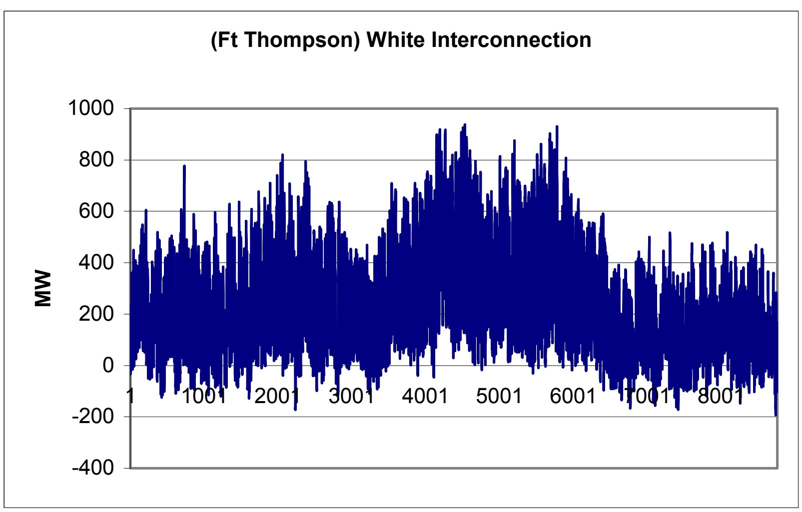
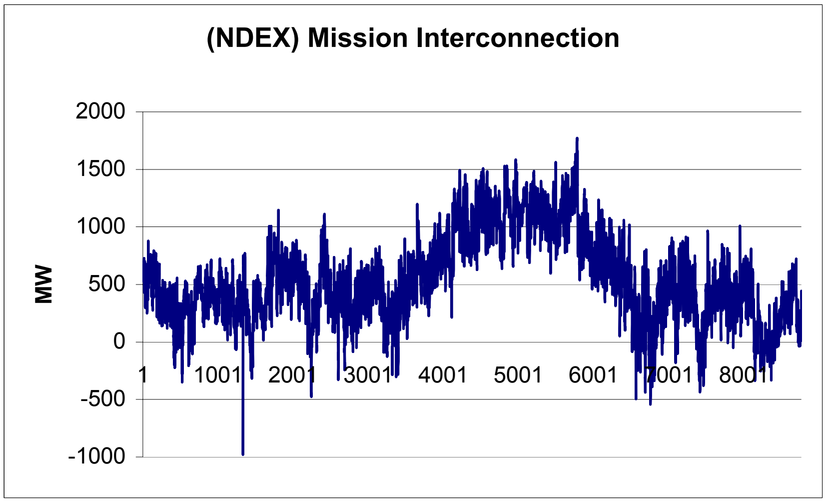
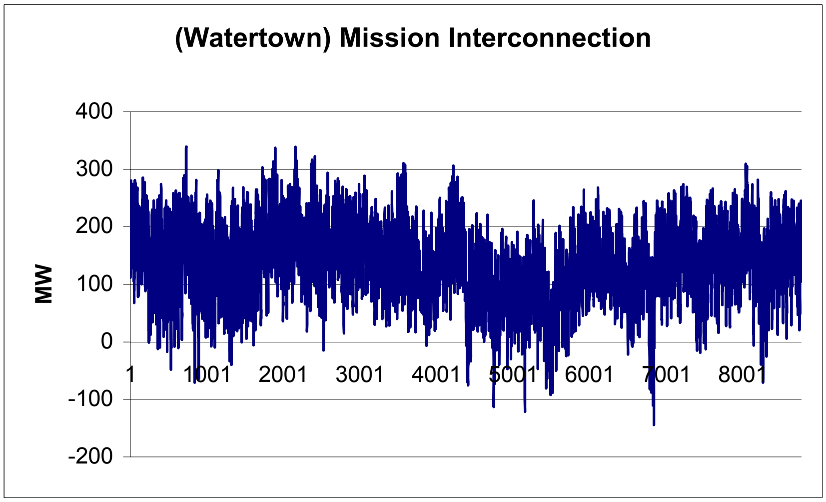
1000
500
0
-500
-1000
1
1001
2001
3001
4001
5001
6001
7001
8001

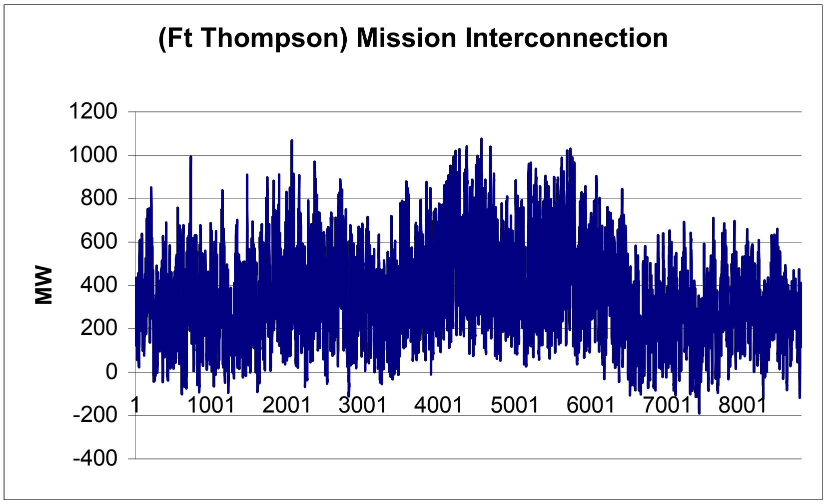

Watertown Interface with White Wind Site
MW
500
400
300
200
100
0
-100
-200
1
1001
2001
3001
4001
5001
6001
7001
8001


(Ft Thompson) White Interconnection
MW
1000
800
600
400
200
0
-200
-400
1
1001
2001
3001
4001
5001
6001
7001
8001

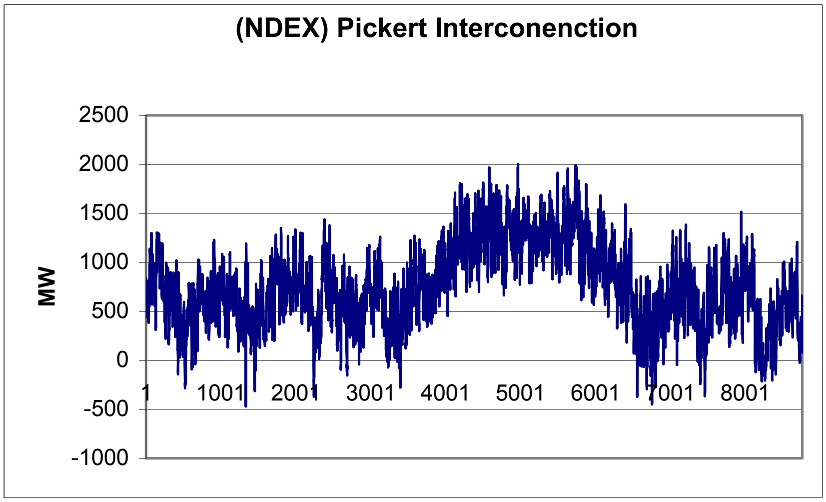
MISSION SITE

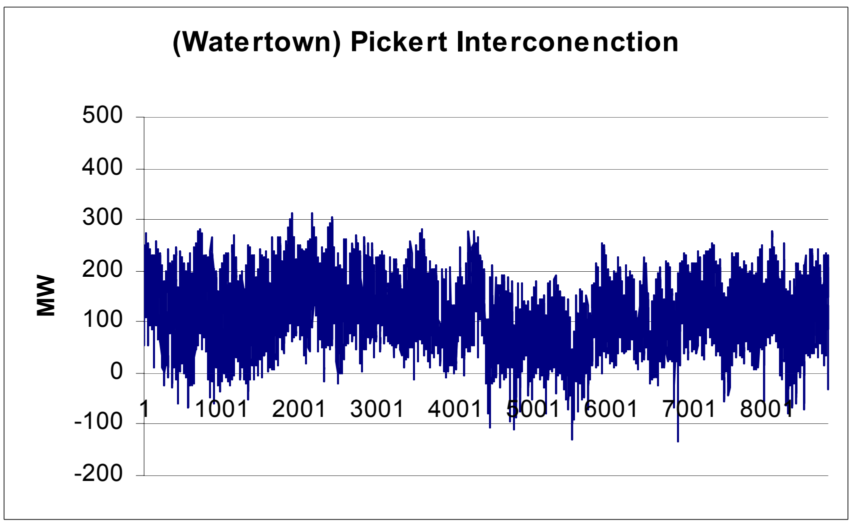


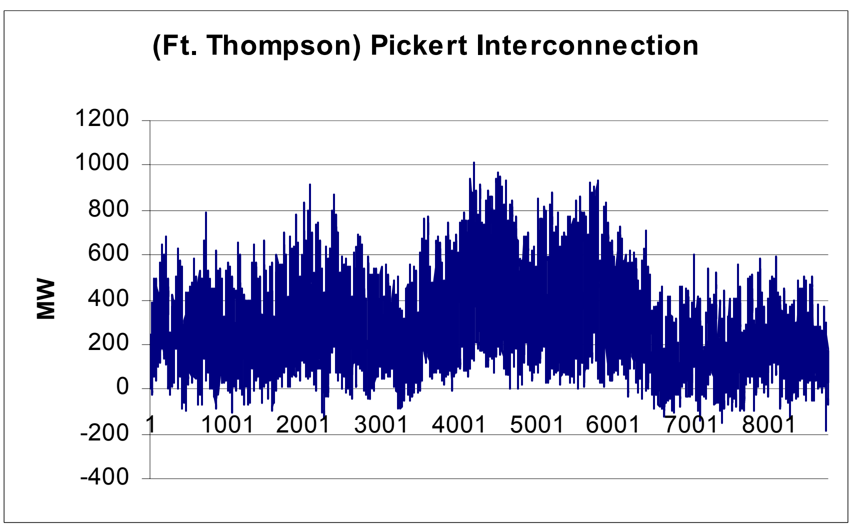




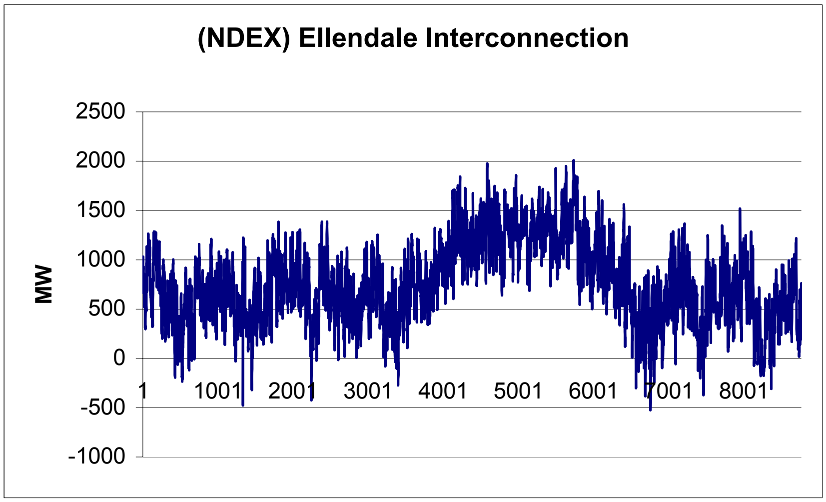
PICKERT SITE

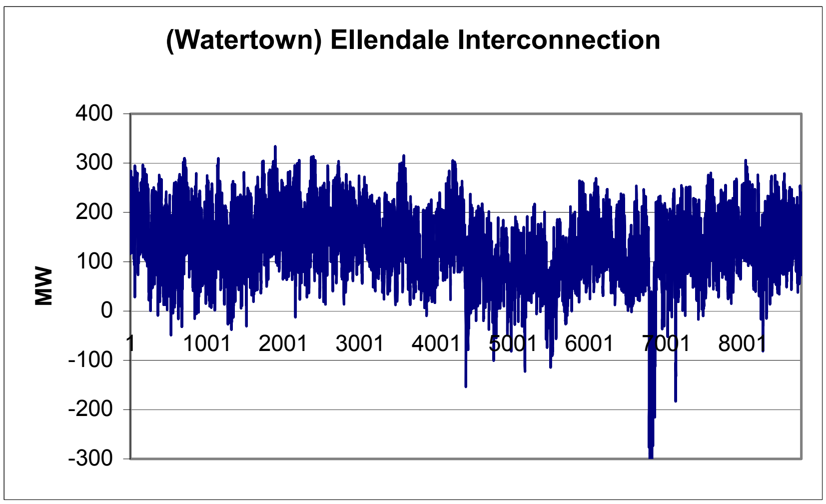


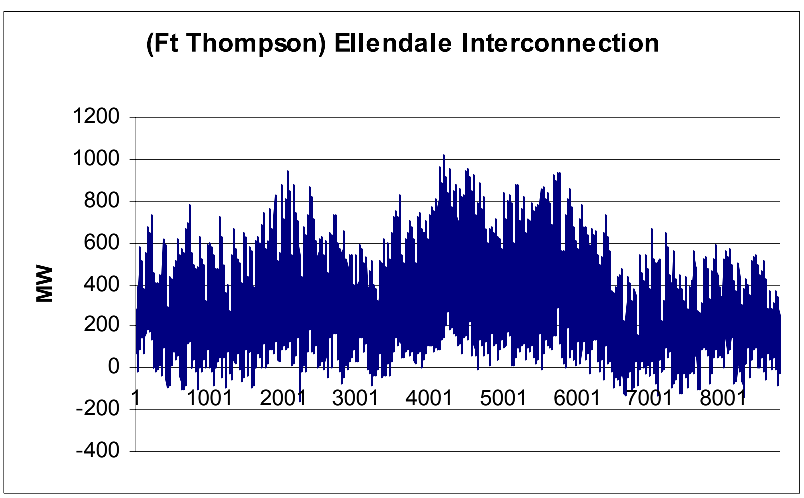




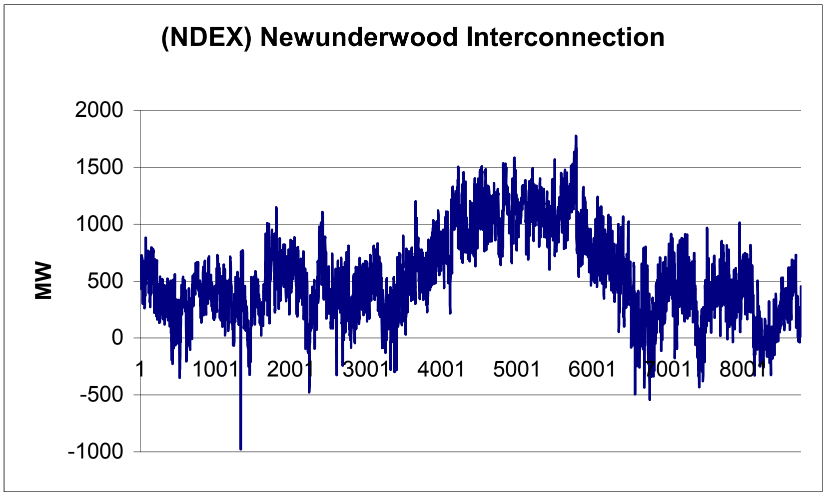
ELLENDALE SITE

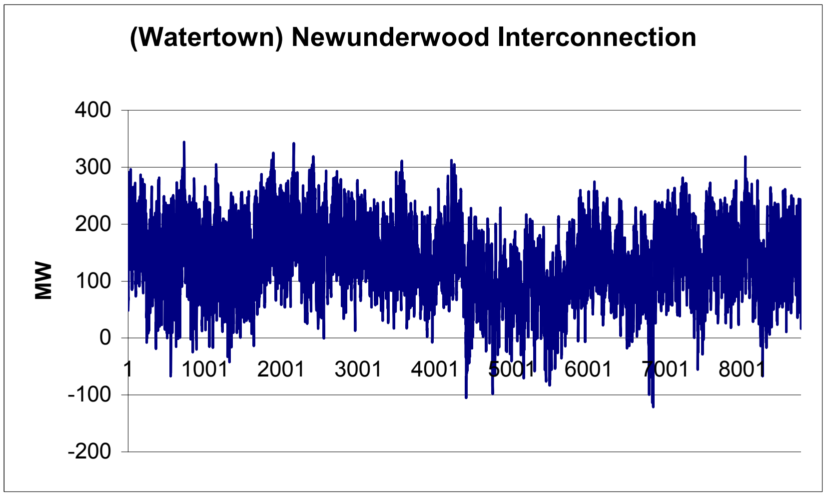


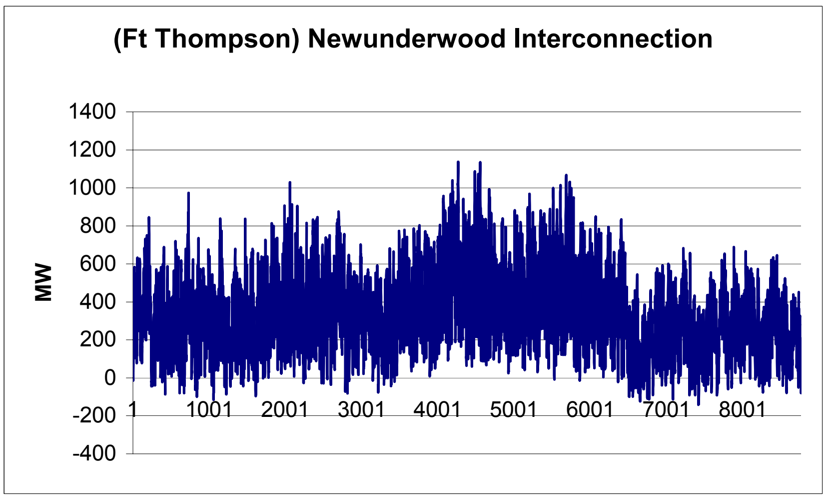




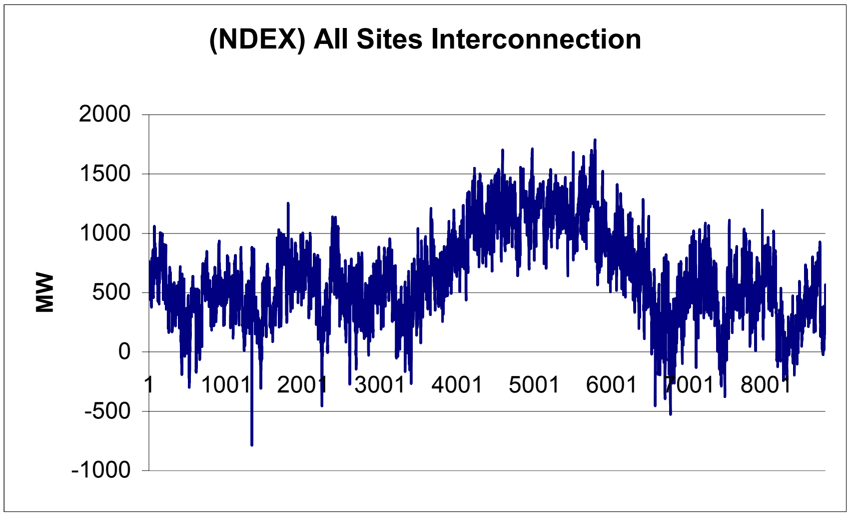
NEW UNDERWOOD SITE

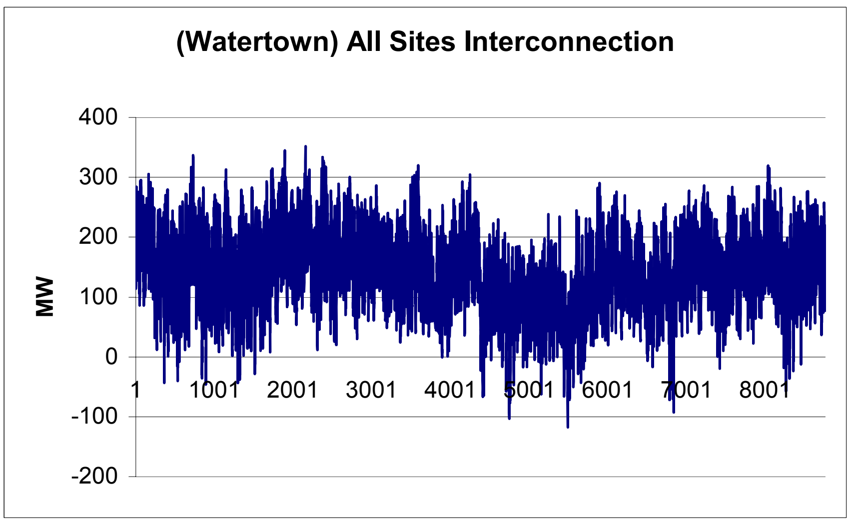


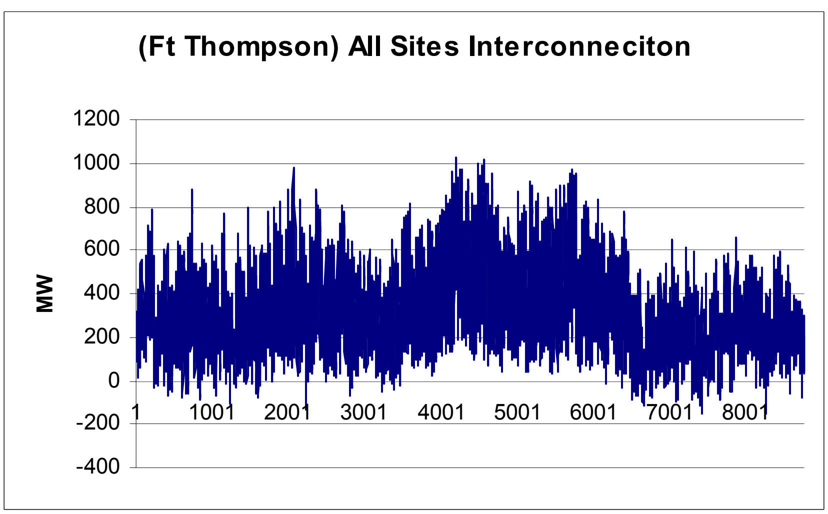




ALL SITES


(NDEX) All Sites Interconnection
MW
2000
1500
1000
500
0
-500
-1000
1
1001
2001
3001
4001
5001
6001
7001
8001


(Watertown) All Sites Interconnection
MW
400
300
200
100
0
-100
-200
1
1001
2001
3001
4001
5001
6001
7001
8001


(Ft Thompson) All Sites Interconneciton
MW
1200
1000
800
600
400
200
0
-200
-400
1
1001
2001
3001
4001
5001
6001
7001
8001

DAKOTA WIND TRANSMISSION STUDY

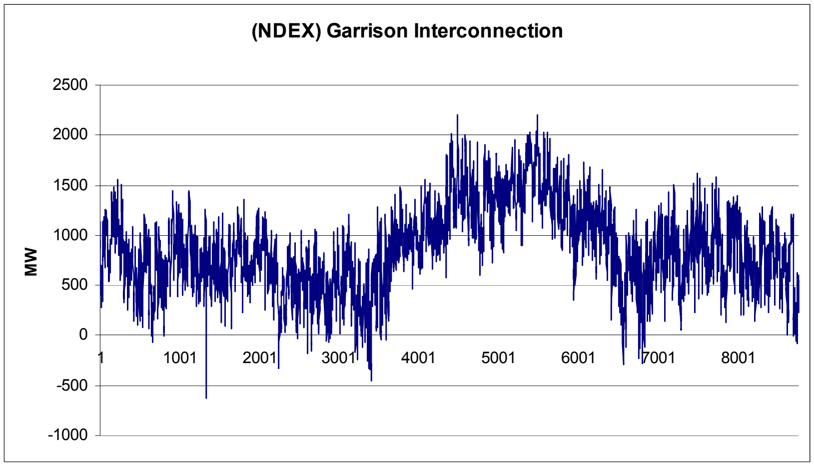
TASK 1
Non-Firm Transmission Potential to Deliver Wind Generation

APPENDIX B

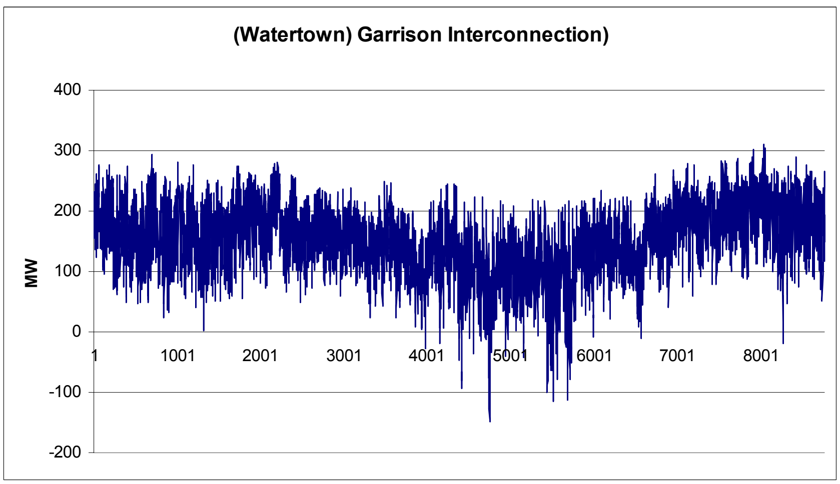
RESULTS FROM GRIDVIEW ON HIGH HYDRO GENERATION

Garrison Interconnection

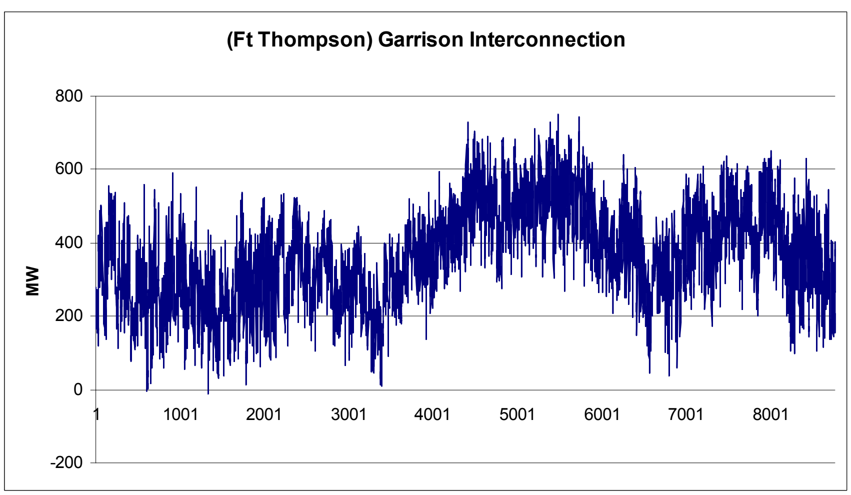
NDEX Interface:



Watertown Interface

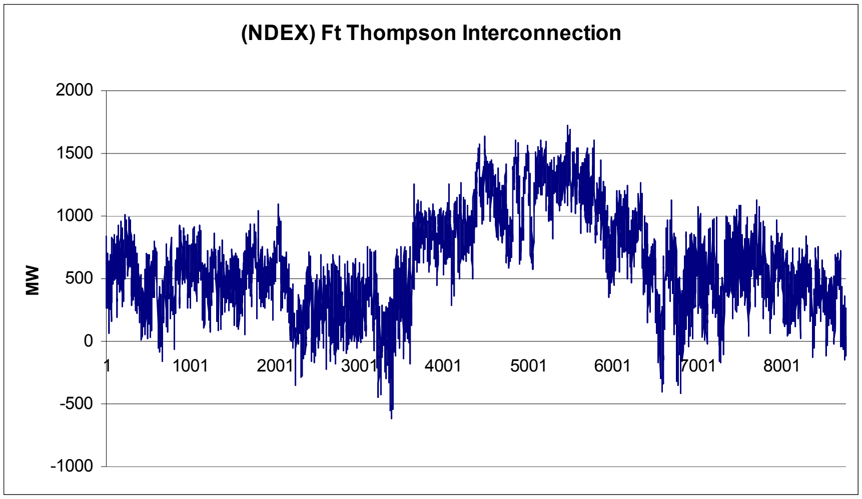


Ft Thompson Interface:

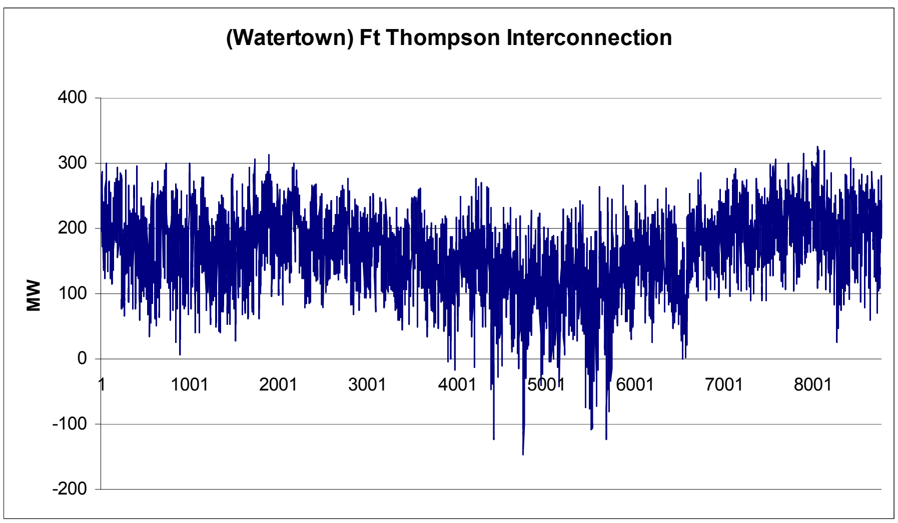


Ft Thompson Interconnection

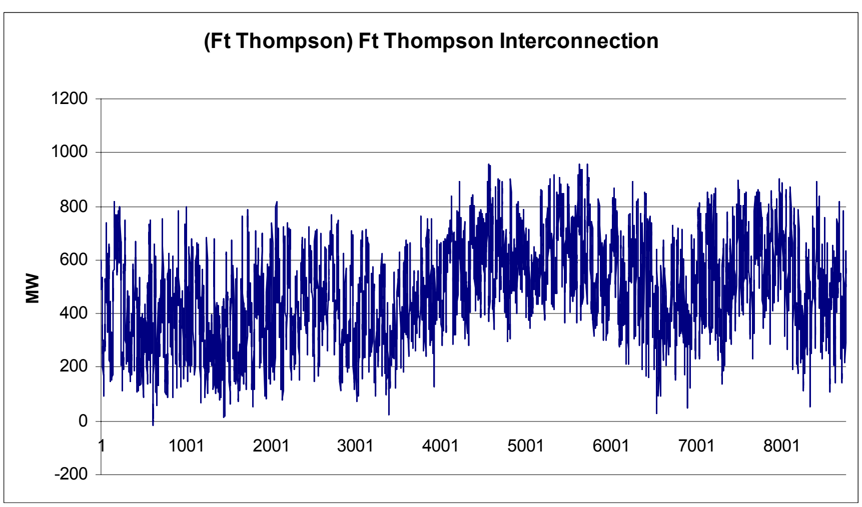
NDEX Interface:



Watertown Interface

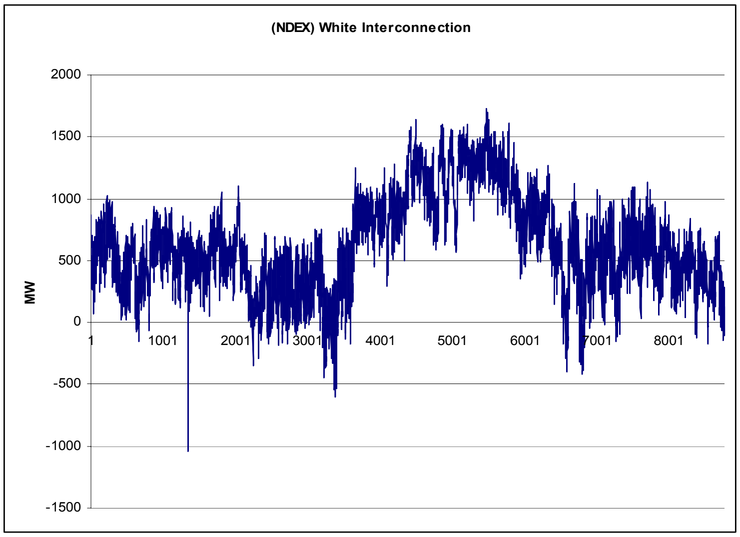


Ft Thompson Interface:

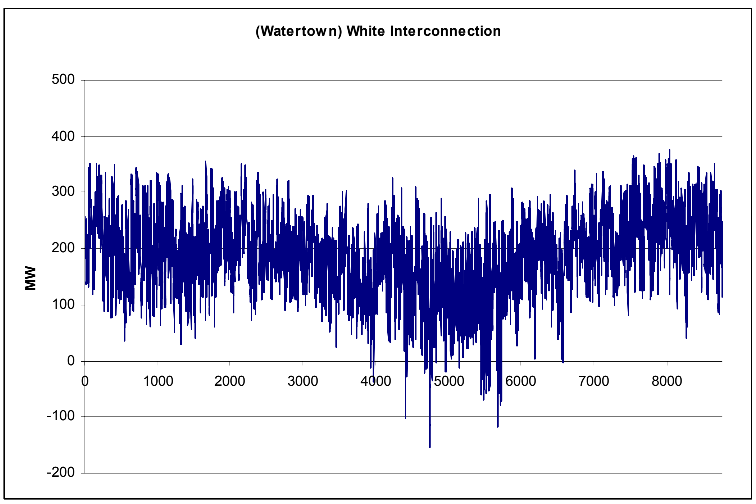


White Interconnection

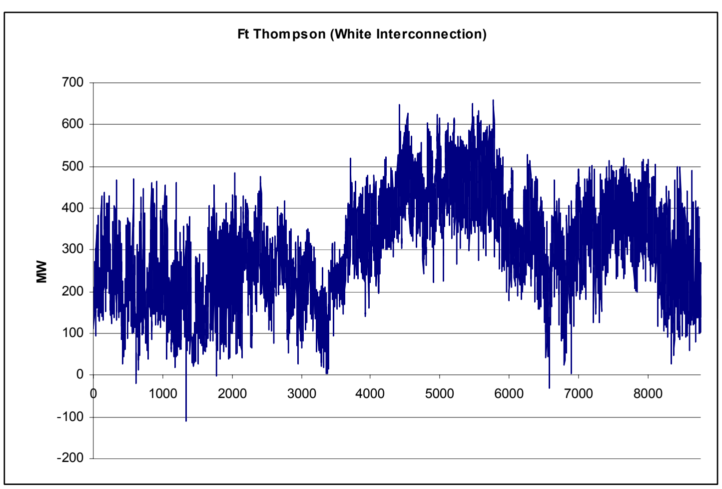
NDEX Interface:



Watertown Interface

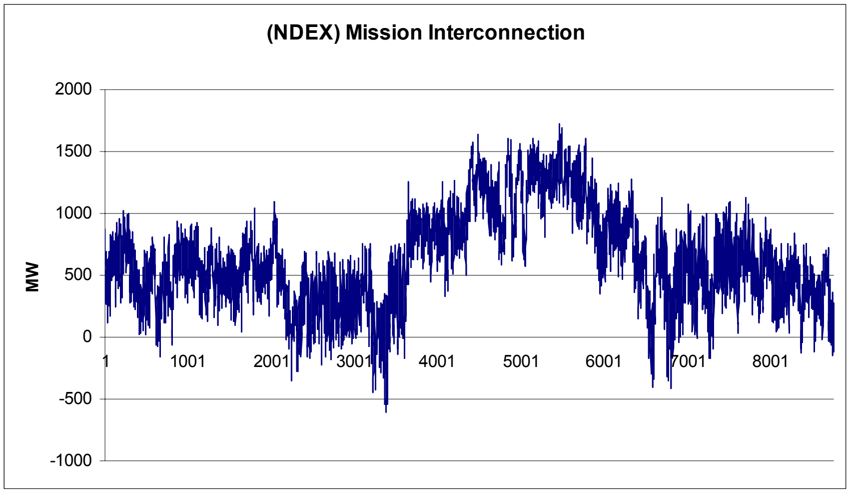


Thompson Interface:

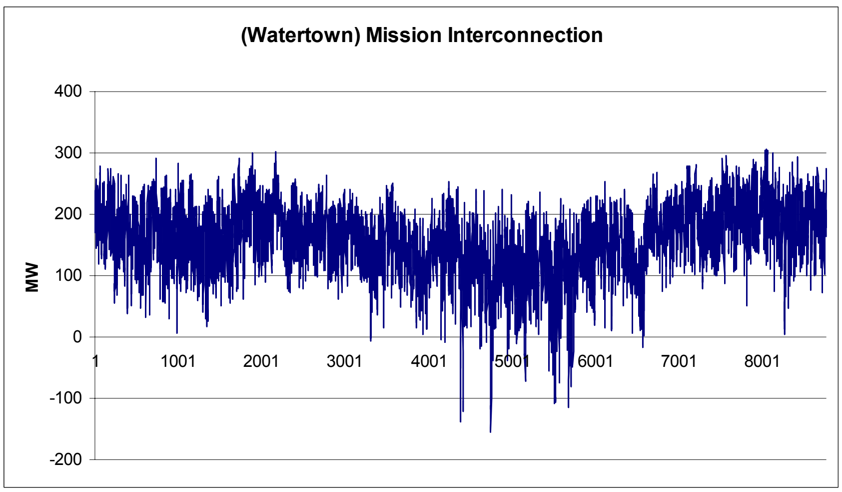


Mission Interconnection

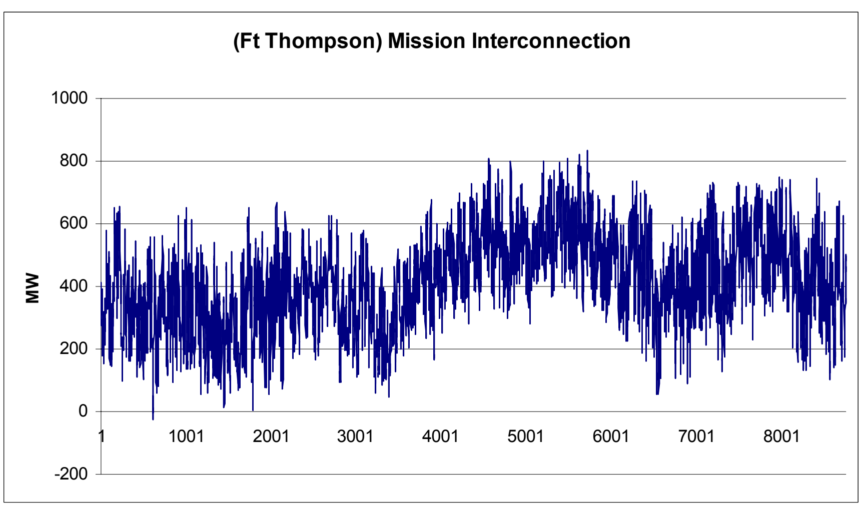
NDEX Interface:



Watertown Interface

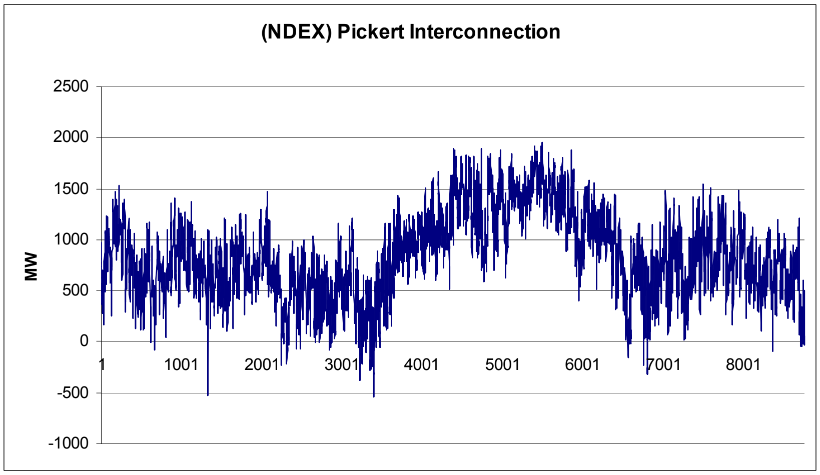


Ft Thompson Interface:

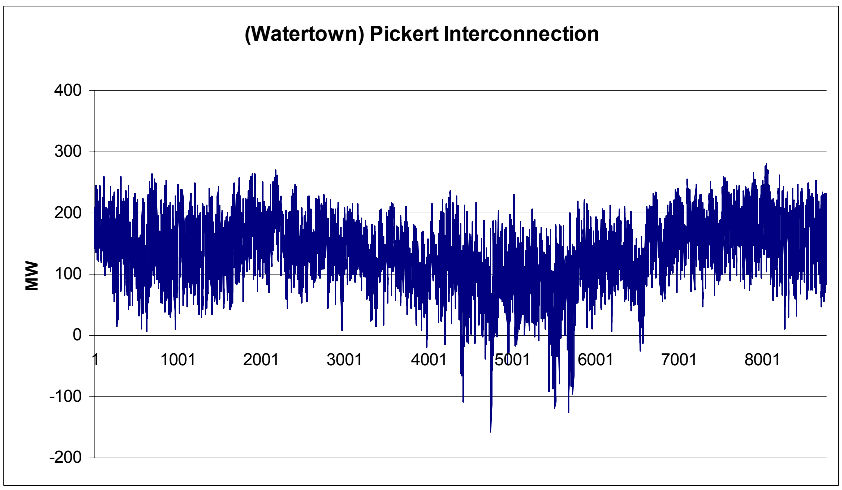


Pickert Interconnection

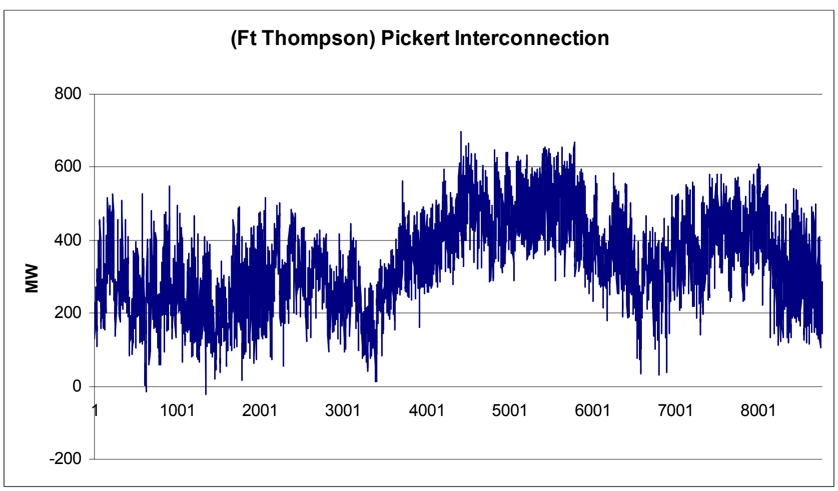
NDEX Interface:



Watertown Interface

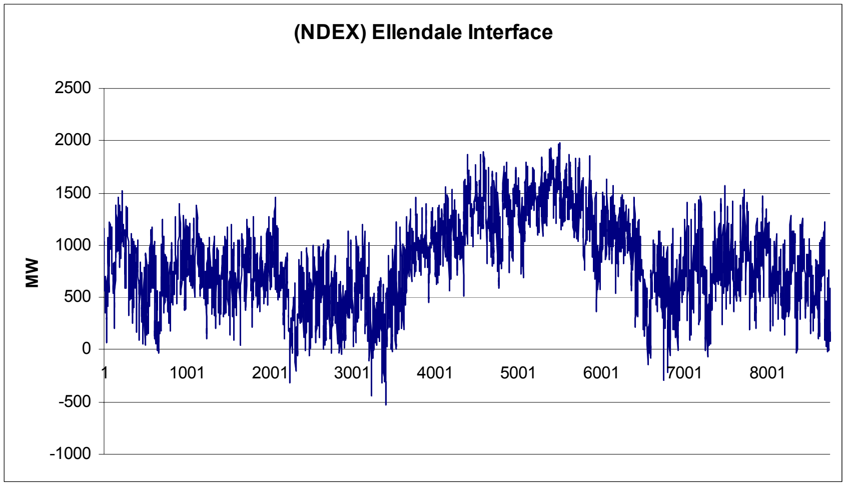


Ft Thompson Interface:

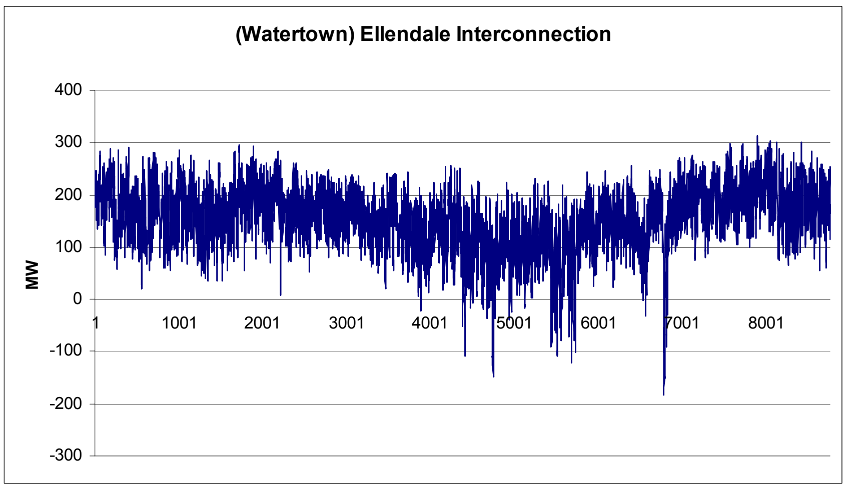


Ellendale Interconnection

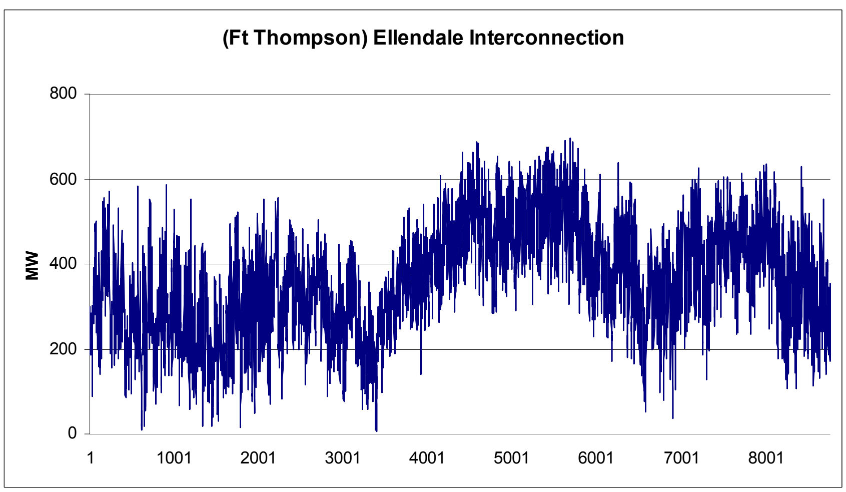
NDEX Interface:



Watertown Interface

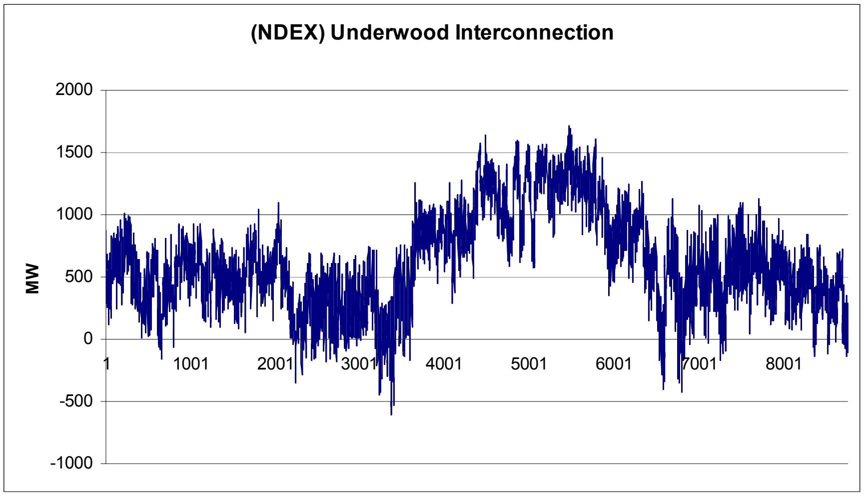


Ft Thompson Interface:

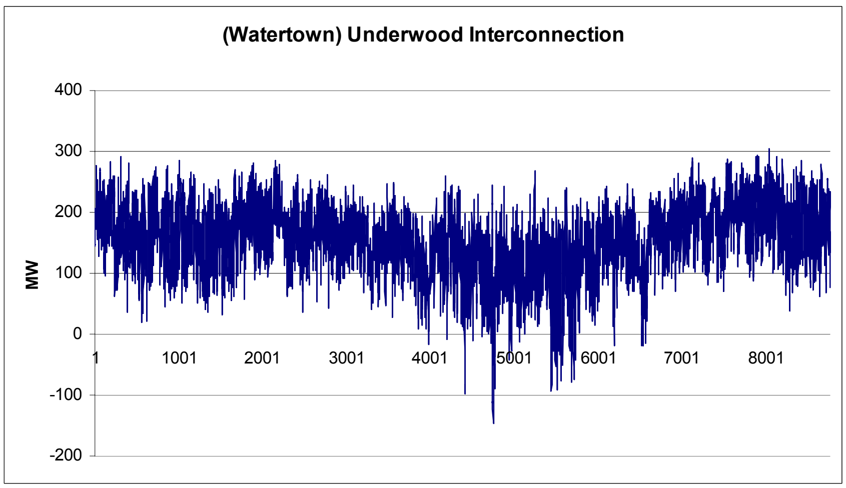


Underwood Interconnection

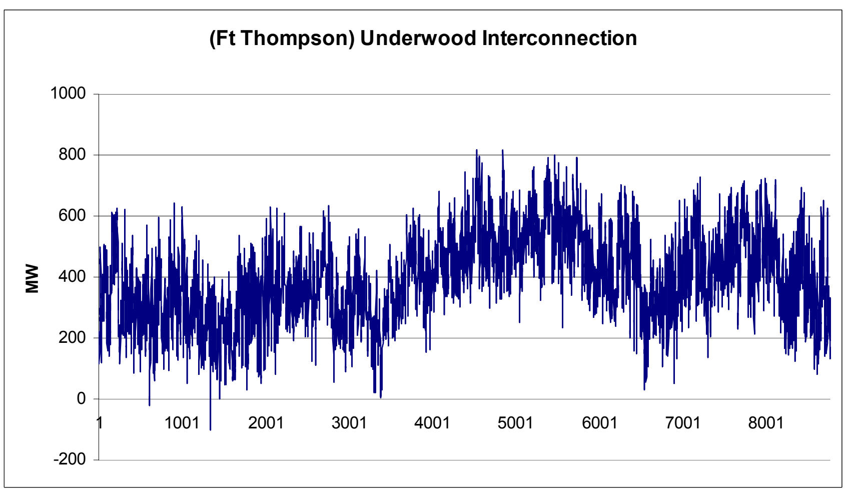
NDEX Interface:



Watertown Interface

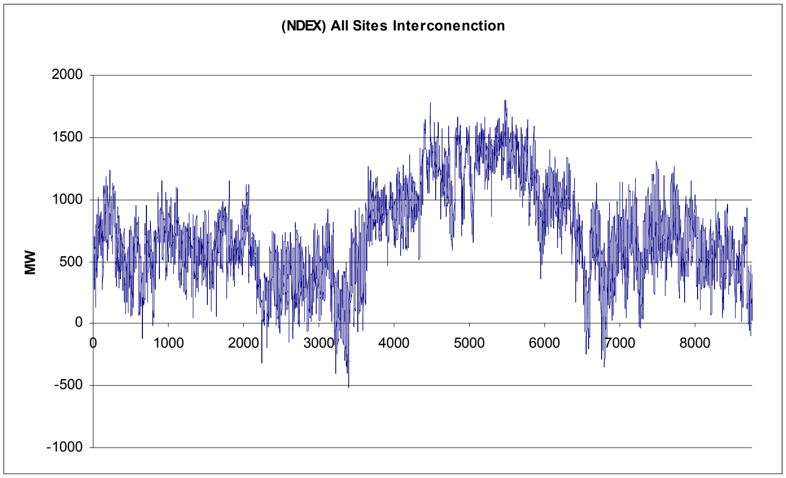


Ft Thompson Interface:

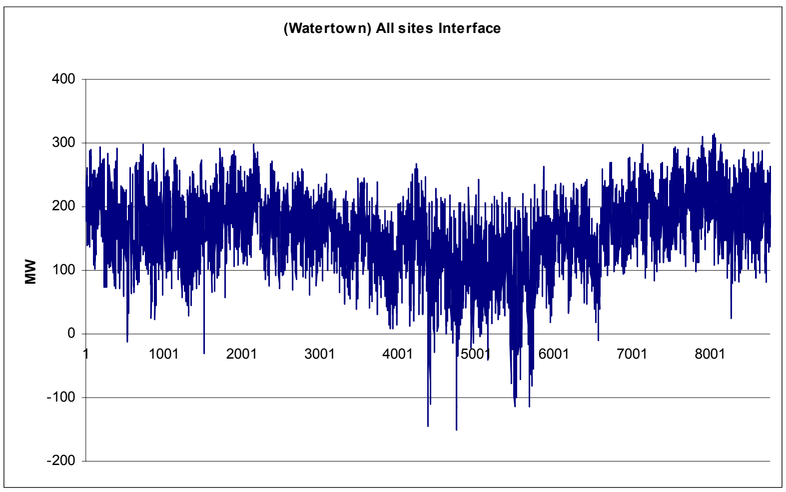


All Sites Interconnection

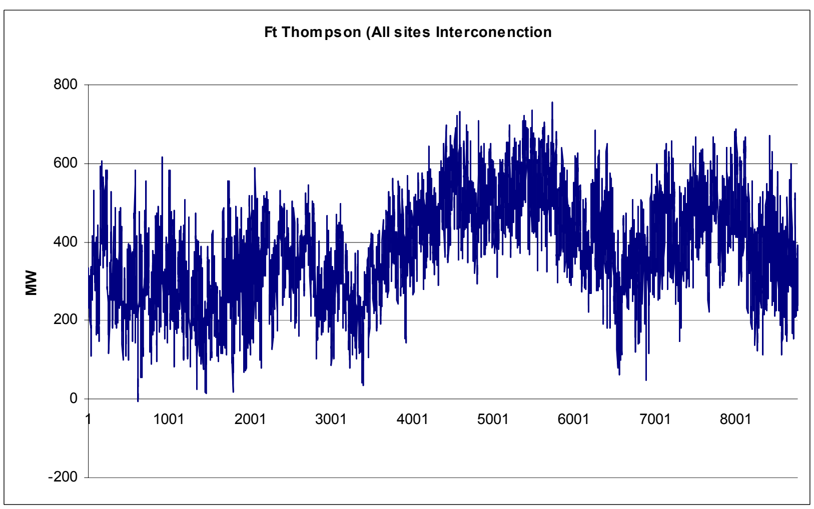
NDEX Interface:



Watertown Interface



Ft Thompson Interface:



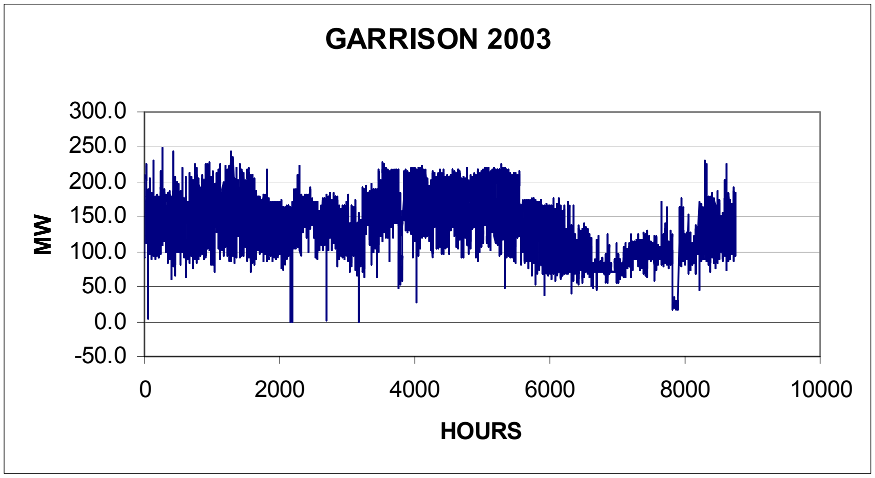
DAKOTA WIND TRANSMISSION STUDY

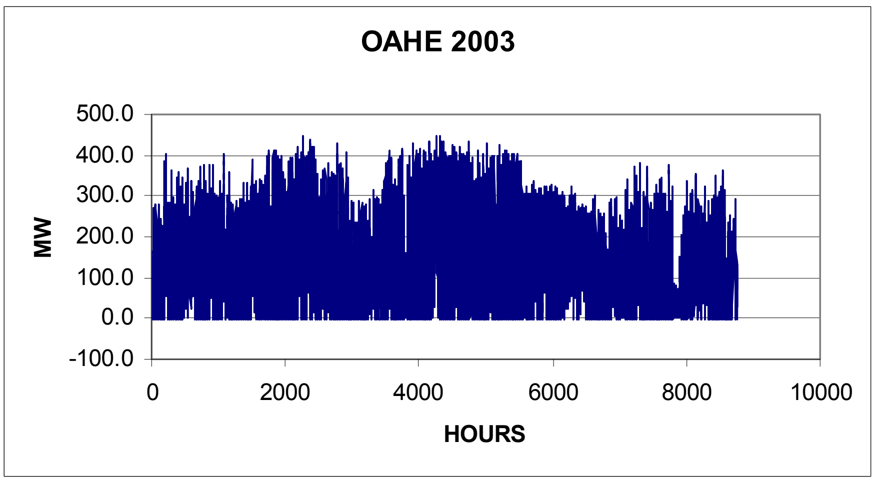
TASK 1
Non-Firm Transmission Potential to Deliver Wind Generation

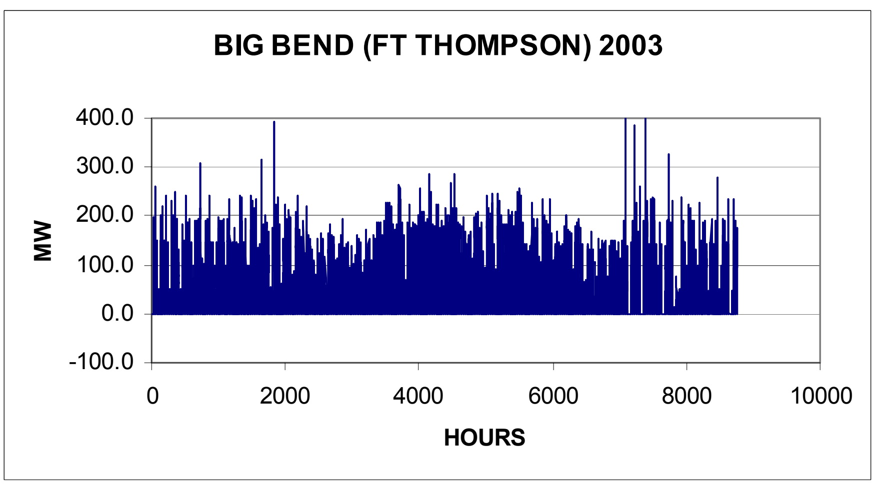
APPENDIX C

COMPARISON OF LOW AND HIGH HYDRO GENERATION

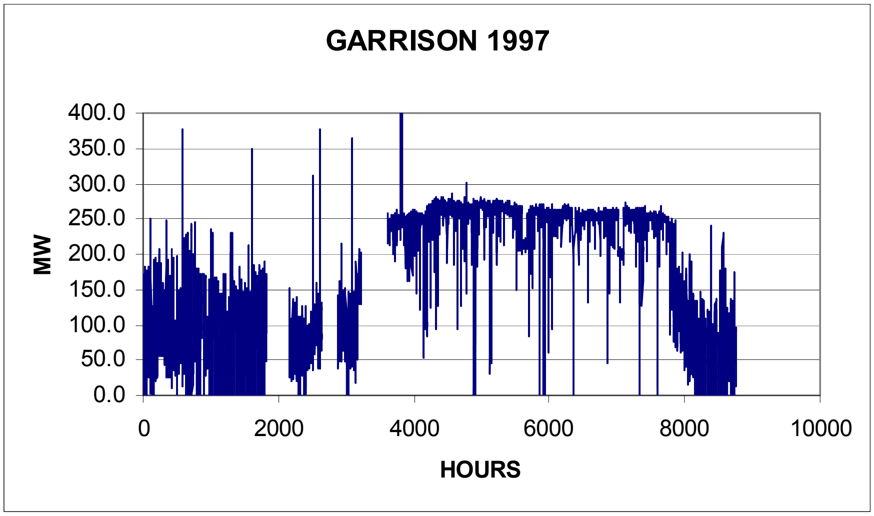
BASE CASE 2003 PLOTS – LOW HYDRO CASE

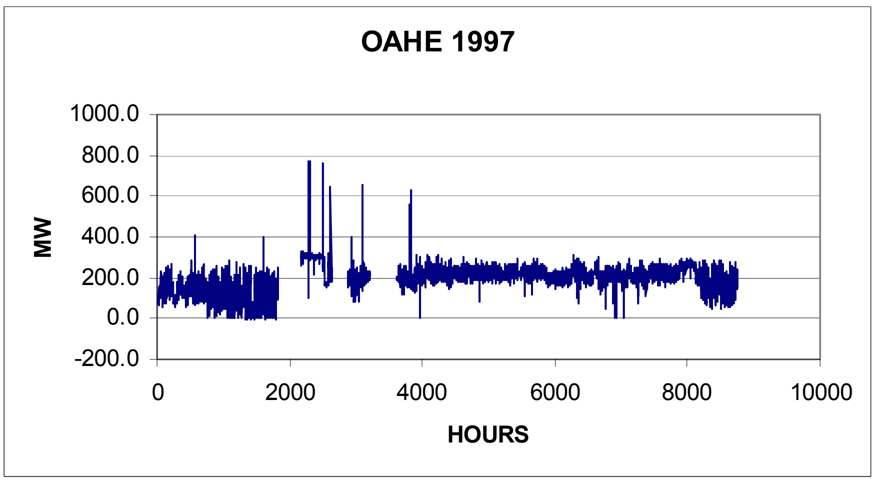


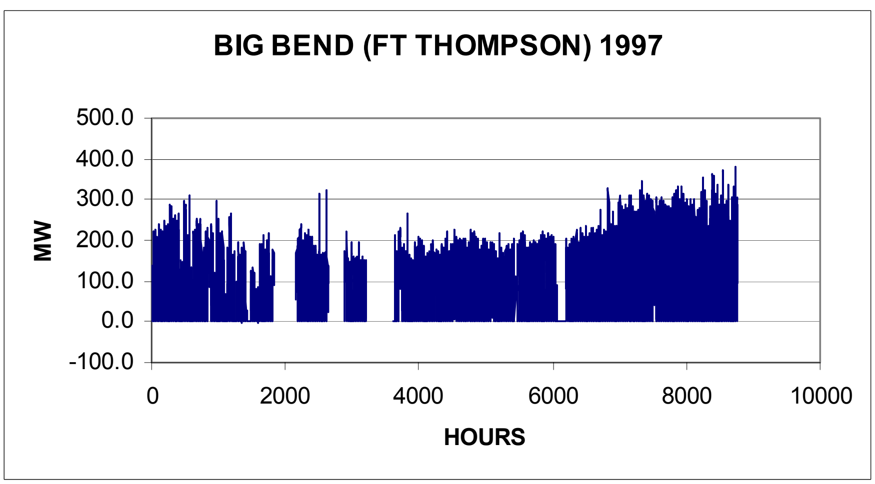




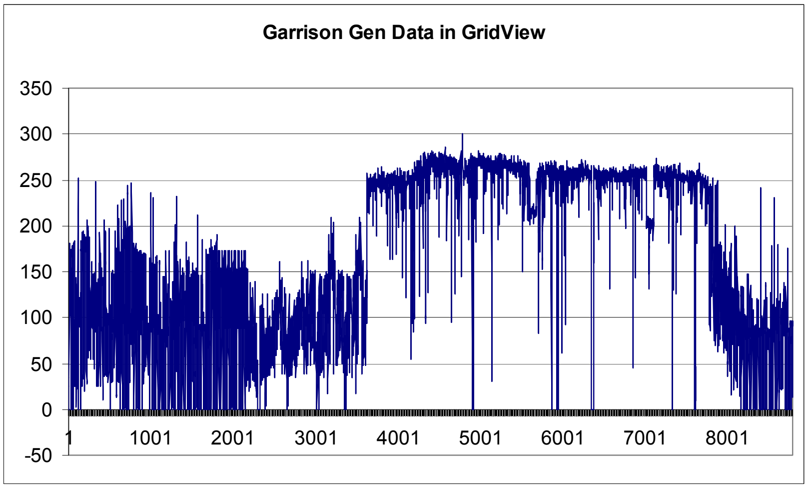
1997 HIGH HYDRO CASE – RAW DATA WITH MISSING INFORMATION

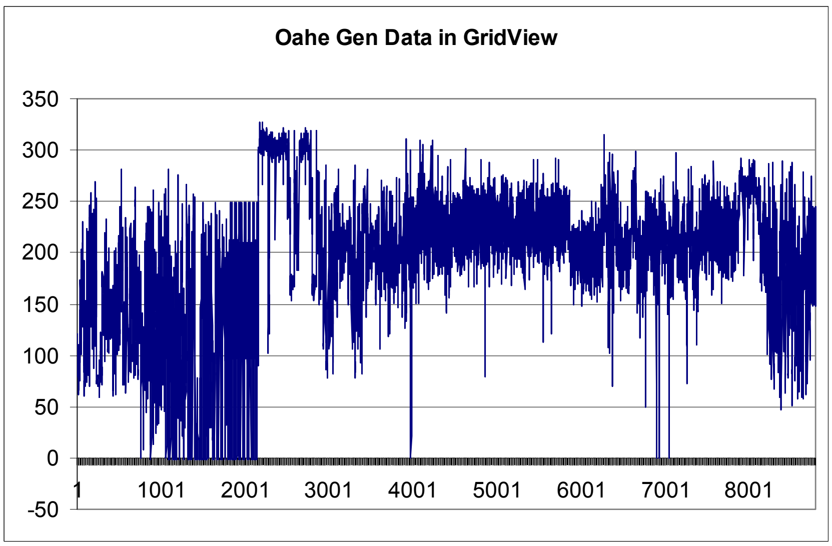


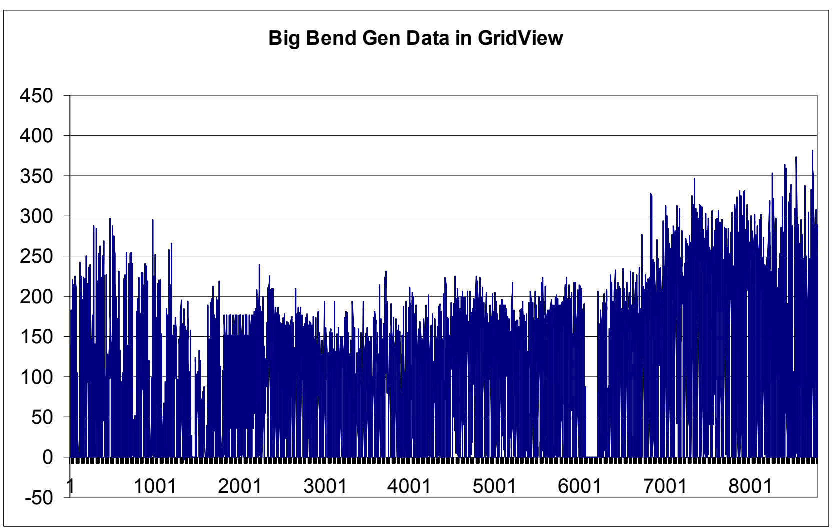




1997 HIGH HYDRO CASE – DATA USED IN GRIDVIEW







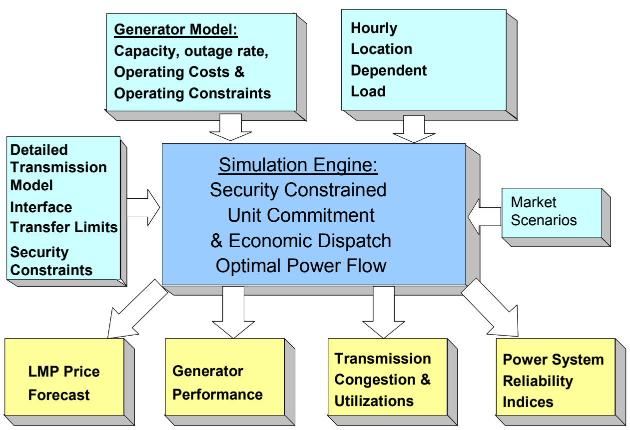
APPENDIX D

GRIDVIEW INFORMATION

GridView

-Modeling to Predict Economic Value-

GridView is a powerful energy market simulation and analysis tool designed to deal with the most challenging issues facing decision makers in the electric energy industry today. In GridView, advanced analysis methodology combines generation, transmission, loads, fuels, and market economics into one integrated framework to deliver location dependent market indicators, transmission system utilization measures and power system reliability and market performance indices. It provides invaluable information for both generation and transmission planning, operational decision making and risk management.

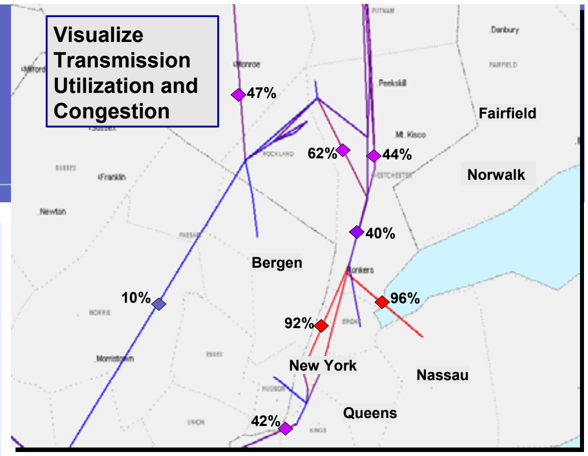


Integrated Modeling of Electric Systems & Market Economics

GridView uses state-of-the-art modeling technology to simulate security constrained unit commitment and economic dispatch in large-scale transmission networks. It produces unit commitments and economic dispatches that respect the physical laws of power flow and transmission reliability requirements. As such, the generation dispatch and market clearing price are feasible market solutions within real power transmission networks. This makes GridView fundamentally different from the competition. Other industry models bear little resemblance to real power systems and ignore transmission constraints. Therefore, GridView coupled with graphic interface and easy-to-use system makes it an unique analytical tool for decision-making.

GridView is used by planners, engineers, energy traders and consultants to analyze challenging issues facing them today. Built-up databases and service experiences around GridView include all NERC regions in the US and some overseas power systems. Major studies have been performed for various market participants, policy makers, power plant and transmission developers, and generation and transmission companies.

GridView



Transmission Studies

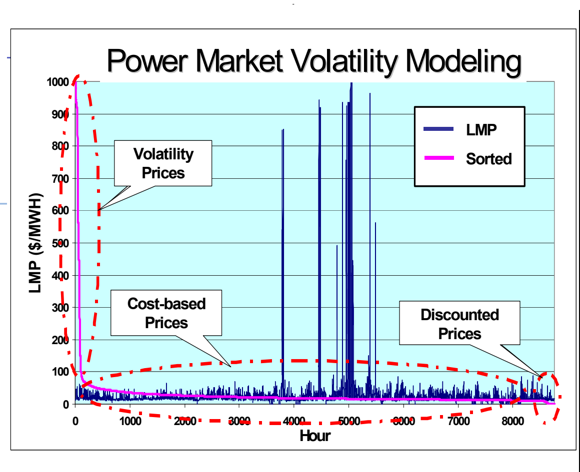
- Asset utilization
- Bottleneck identification
- Congestion mitigation optimization
- Market based probabilistic reliability assessment
- Transmission expansion planning and alternative evaluation
- Identification and economic assessment of transmission projects

Generation Studies

- Plant siting and cycle optimization
- Bidding strategy assessment
- Asset evaluation and management
- Portfolio optimization and risk management
- Plant market performance analysis
- Generation interconnection evaluation

Market Studies

- Price forecasting and volatility analysis
- Benefit and cost evaluation for RTOs/ITCs and stakeholders
- Congestion management and value of congestion relief
- Evaluation of forward energy contracts
- Capacity value studies
- Market power analysis and monitoring
- Market performance benchmarking
- Alternative market designs



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